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S/S By Fm 5-412
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FM 5-333

CONSTRUCTION MANAGEMENT

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NO. 1

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CONSTRUCTION MANAGEMENT

FM 5-333, 17 February 1987, is changed as follows:

1. Line through and make necessary changes as indicated below:

Page 10-3, Table 10-1, reads, "BRICK, CONCRETE BLOCK, AND MORTAR-BOUND RUBBLE". Change to read, "STRUCTURAL TILE".

Page 10-4, Table 10-2, reads, "STRUCTURAL TILE". Change to read, "BRICK, CONCRETE BLOCK, AND MORTAR-BOUND RUBBLE".

2. File this change sheet in front of the publication for reference purposes.

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**FIELD MANUAL
NO. 5-333**

***FM 5-333
HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, 17 February 1987**

CONSTRUCTION MANAGEMENT

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Preface

This manual will guide military personnel in using sound management practices. It is intended for use by battalion and company level project managers. It contains information for planning, scheduling, and controlling projects to both nuclear and nonnuclear warfare.

Users of this publication are encouraged to submit recommended changes and comments to improve the publication. Comments should be keyed to the specific page, paragraph, and line of the text. Reasons should be provided for each comment to ensure understanding and complete evaluation. The proponent agency of this publication is the US Army Engineer School. Submit changes for improving this publication on DA Form 2028 (Recommended Changes to Publications and Blank Forms) and forward to Commandant, US Army Engineer School, ATTN: ATZA-TD-P, Fort Belvoir, Virginia 22060-5291.

Unless otherwise stated, whenever the masculine or feminine gender is used, both men and women are included.



Chapter

Mission of Army Engineer Construction Management

THEATER OF OPERATIONS CONSTRUCTION

MAJOR FUNCTIONS

Engineer construction functions in the theater of operations (TO) are the design, construction, repair, rehabilitation, and maintenance of structures. These include roads, bridges, inland waterways, ports, industrial facilities, logistic support facilities, storage and maintenance areas, protective emplacements, hospitals, camps, training areas, housing, administrative space, and utilities. Other functions are the design, construction, and rehabilitation of railroads, airfields, and heliports.

COMMAND RESPONSIBILITIES

Each engineer command, brigade, group, and battalion is authorized a staff to assist the commander. The composition of these staffs and the duties of the staff members vary with the type of organization, its mission, and its echelon of command. Generally, engineer staffs at group or higher echelons perform as planners, designers, advisors, supervisors, inspectors, and coordinators. At battalion level the staff members are operators. They supervise the implementation of the plans of the higher headquarters. For example, upon receipt of a task directive from brigade, the group staff designs the project; plans and assigns the tasks; and directs the battalions, which are the operating units, to perform the tasks.

BATTALION RESPONSIBILITIES

Combat battalions (heavy) provide—

- Construction or rehabilitation of lines of communications, bridges, forward tactical and cargo airfields, and heliports.
- General construction of buildings, structures, and related facilities.
- Limited reconstruction of railroads, railroad bridges, and ports.
- Limited bituminous paving.
- Minor protective construction.

When supported by attachments of specialized personnel and equipment, combat battalions (heavy) provide—

- Large-scale bituminous and portland cement paving operations.
- Large-scale quarrying and crushing operations.
- Major railroad and railroad bridge reconstruction.
- Major port rehabilitation.
- Major protective construction.
- Pipeline and storage tank construction.
- Fixed and tactical bridges.

Engineer combat battalions provide—

- Construction, repair, and maintenance of roads, fords, culverts, landing strips, heliports, command posts, supply installations, buildings, structures, and related facilities.
- Preparation and removal of obstacles, to include minefields.
- Construction and placement of deceptive devices and technical assistance in camouflage operations.
- Site preparation for air defense artillery units.
- Construction of defensive installations.
- Engagement in river-crossing operations, to include assault crossing of troops and construction of tactical rafts and bridges.

For additional information on engineer unit capabilities, see TM 5-304.

GUIDELINES

Construction and repairs in a theater of operations contribute to the sustainment and efficiency of field armies. In an active theater only essential construction work and development of installations and facilities are performed. The quality of construction does not exceed standards established by the theater commander. Modified emergency construction and the use of permanent materials (tile, stucco, concrete, steel) are authorized only in the following situations:

- Such work is required by an agreement with the government of the country in which the facilities are to be located. Prior approval of Headquarters, Department of the Army is also required.
- Materials normally used in emergency construction are not available or cannot be made available in time to meet schedules. However, permanent construction materials are available or can be made available in time to meet schedules, at no increase in total cost. When permanent materials are used, the interior and exterior finishes of structures must be in keeping with emergency construction standards. The permanency of any structure should be consistent with military needs at the time.

Standard Designs. For hospitals, depots, and shelters standard designs are used in active theaters of operations. They present the simplest method of using standard materials to build acceptable installations. They are designed to reduce the variety of materials required, ensure uniformity and facility standards, simplify procedures, and minimize costs.

Army Facilities Components System (AFCS). The Army Facilities Components System (AFCS) provides logistic and engineering data organized, coded, and published to assist in planning and executing theater of operations construction. The system determines personnel and material requirements, as well as cost, weight, and volume of the material needed for construction.

The AFCS provides construction planning data for—

- Contingency, base development, construction and logistical planners by presenting a flexible planning tool for theater of operations construction and construction support missions.
- Construction units for various utilities structures, facilities, installations and construction tasks required by the Army and Air Force in support of military missions in a theater of operations.
- Logistical commands and supply agencies in requisitioning, identifying items, costing, and other related supply functions.

The AFCS consists of a series of four Department of the Army Technical Manuals.

TM 5-301, Army Facilities Components System—Planning. This manual, which is generally used by military planners, contains Installation, Facility and Prepackaged Expendable Contingency Supply (PECS) summaries. The TM 5-301 series is published in four volumes, each addressing a separate climatic zone. The summaries appearing in the four volumes include cost, shipping weight, volume, and man-hours required for construction.

- TM 5-301-1 (Temperate) covers geographical areas where mean annual temperatures are between +30° and +70° Fahrenheit.
- TM 5-301-2 (Tropical) covers geographical areas where the mean annual temperatures are higher than +70° Fahrenheit.
- TM 5-301-3 (Frigid) covers geographical areas where the mean annual temperatures are lower than +30° Fahrenheit.
- TM 5-301-4 (Desert) covers geographical areas which are arid and without vegetation.

TM 5-302, Army Facilities Components System—Designs. This five-volume manual contains site and utility plans for the installation, construction drawings, and construction detail drawings for the facilities. New designs are added, and obsolete designs are revised as required to meet the construction needs of the Army. Drawings stamped “Under Revision, Do Not Use” should not be used for construction or planning purposes. However, drawings stamped “Under Revision” may be used for planning purposes.

TM 5-303, Army Facilities Components System—Logistic Data and Bills of Materials. This manual is generally used by planners, builders, and suppliers in identifying items contained in the bills of materials.

TM 5-304, Army Facilities Components System—User Guide. This manual explains how to use the system.

SPECIAL NEEDS

Construction in a TO requires speed, economy, flexibility, decentralization of authority, and establishment of priorities.

Speed. Fundamental to all activities in a theater of operations, speed is especially important to the engineer. Recognizing the importance of speed, the Corps of Engineers has developed and adopted certain policies and practices that satisfy this vital requirement.

Standardization. Standardized plans save time in design and construction. In building, they permit production-line methods in the prefabrication of construction members. They increase the efficiency of working parties who can repeat erection procedures until they become almost mechanical. Standardization of construction is highly desirable in time of war.

Simplicity. Construction must be simple during war because of shortages of personnel, materials, and time. The available labor uses the simplest methods and materials to complete installations in the shortest time.

Necessities and life expectancy. Military engineering in the theater of operations is concerned with only the bare necessities and temporary facilities. Adequate provisions are made for safety, but they are not as elaborate as in civilian practice. For example, local green timbers are often used to construct wharves or pile-bent bridges even though marine borers will rapidly destroy the timbers. By that time, the focus of military effort will have changed. Sanitary facilities may consist of nothing more than pit latrines. Using valuable time for anything more permanent is not justified. In short, quality is sacrificed for speed and economy.

Phase construction. Construction in various phases provides for the rapid completion and use of parts of buildings or installations before the entire project is completed. Specialized crews or working parties, such as fabricating, foundation, plumbing, and roofing crews, may be organized. Each crew performs a specific task and moves on to the next site. Large building projects, such as hospitals, depots, and permanent cantonment areas, are suitable to this type of construction.

Another system of phase construction involves the refinement and evolution of an installation. Construction of a depot will serve as an illustration. Initially, storage is provided in structural frame buildings with footings and roof cladding, but without wall cladding. Later, concrete floors and sidings may be provided and development may progress in phases until the facilities are adequate.

Both systems are used and have the same objective: to have the using service occupy the first building while the second building is being constructed. Phase construction is usually inefficient, but this is offset by the maximum use of facilities at the earliest possible time.

Existing facilities. The use of existing facilities contributes greatly to the essential element of speed. The advantages often influence the point of attack in military operations.

Economy. Equipment, personnel, and materials must be used effectively and efficiently since these resources are limited.

Personnel. Despite the mechanization of modern warfare, battles are still won and territory is occupied by soldiers. For this reason, highest priorities on personnel go to units in contact with the enemy. In a combat support role, the engineers have the problem of accomplishing construction quickly with limited personnel. Conservation of labor is important. Every engineer must function at peak efficiency for long hours. Assignments must be carefully planned and coordinated. Projects must be well organized and supervised. Personnel must be well cared for and carefully allocated.

Equipment. Normal peacetime construction equipment cannot handle the requirements of wartime operations, regardless of the location. In the theater of operations, this is especially true because of the destructiveness of opposing forces. The economical use of equipment resources is essential.

Materials. An overseas wartime construction program must be organized to execute the required work in the time allotted and with a minimum of shipped-in tonnage. Local resources must be used, but these are often limited.

Flexibility. A military construction program must be flexible. The ever-changing situation in military construction requires that construction in all stages be adaptable to new conditions. To meet this requirement, standard plans are a part of the Army Facilities Components System and are found in the TM 5-302 series. Alternate materials are permitted and designs give each construction item the maximum number of uses. Theater of operations standard components demonstrate this flexibility. They may be used as an office, barracks, hospital ward, warehouse, or dining facility. Advanced airfields may be expanded into more elaborate installations.

Decentralization of Authority. The dispersion of forces in a theater of operations requires that engineer authority be decentralized. The engineer in charge of operations at a particular locality must have authority equal to responsibilities.

Establishment of Priorities. A priority system must be established to determine how much engineer effort will be devoted to a single task. While detailed priority systems are normally the concern of lower echelon commands, all levels of command, beginning with the theater commander, will frequently issue directives to serve as guides for detailed systems. Priority ratings are usually listed for items as first, second, third, fourth, and so on. If a priority rating contains several items that might be worked on concurrently, these items are numbered consecutively to show their relative standing. For example, a theater army commander might list the following priorities:

- First priority: initial beach landing and docking facilities.
- Second priority: item 1, hospital facilities.

- Second priority: item 2, complete wharves and docks.

Note: Details—“which of the hospital facilities shall be first?”—are left to the discretion of the local commander. This conforms to the principle of decentralization, which permits maximum operational freedom for the local commander.

MANAGEMENT THEORY

PRINCIPLES DERIVED FROM EXPERIENCE

Principles of management have been developed from experience and serve as a basis for managing human and material resources. Management principles do not furnish definite formulas for solutions to all management problems.

Examples. The following examples are not infallible laws: they are only guides for action. Effective management should encompass—

- A clearly defined policy understood by those who are responsible for its achievement.
- Subdivision of work, systematically planned and programmed.
- Specific assignment of tasks, and assurance that the tasks are clearly understood.
- Equitable allocation of resources.
- Delegation of authority equal to responsibility.
- Establishment of clear authority relationships.
- Effective and qualified leadership at each echelon.
- Unity of command and purpose throughout an organization.
- Continuous accountability for use of resources and production results.
- Effective coordination of all individual and group efforts.

Improvement Policy. An important principle of Army management states that “continual improvement in systems, methods, and uses of resources is required for continuous effectiveness in operations.” In most of the large nontactical organizations in the Army, management engineering staffs are available to assist commanders and line operators in designing new ways to do work faster, cheaper, and better.

DEFINITIONS

Management definitions are as varied as the authors that write books about the subject. The most effective definition states that management is “the process of getting things done through people.” Construction management may be defined more specifically as “the process of coordinating the skill and labor of personnel using machines and materials to form the materials into a desired structure.” Construction operations involve planning, designing facilities, and supervising construction. Related items are the procurement of materials and equipment and the use of personnel.

The functions of the manager are universal although they may differ in details from one activity to another. These functions should not be confused with the operating tasks such as accounting, engineering, or procurement. The managerial functions are planning, organizing, staffing, directing, and controlling. Each of these is aimed toward accomplishing the objective of the unit. To implement these functions, the manager must understand the objectives, plans, and policies of superiors.

THE PLANNING FUNCTION

Planning means laying out something in advance. Planning creates an orderly sequence and defines the principles to be followed in carrying out the project, and prescribes the ultimate disposition of the results. It serves the manager by pointing out the things to be done, their sequence, how long each and all shall take, and who is responsible for what.

Goals. The goal of planning is to minimize resource expenditures for a given task. Planning aims at producing an even flow of equipment, materials, and labor, and ensuring coordinated effort. Effective planning requires continual checking on events and forecasts, and redrawing of plans to maintain the proper course toward the objective.

Much of the manager’s job will be characterized by the plans to be put into effect. If they are detailed, if they are workable, if the manager has the authority to undertake them and understands what is expected, the manager will require little of a superior’s time.

Steps. Planning involves selection of objectives, policies, procedures, and programs. The core of the manager’s job in planning is decision-making, based on investigation and analysis rather than on snap judgment.

Establish the objective. The objective gives the key for what to do, where to place emphasis, and how to accomplish the objective.

Make assumptions based on facts. For example: weather predictions are based on past weather data; or policies for observing national holidays are expected to continue. These are forecast data and basic policies that apply to the future.

Find and examine alternative courses of action.

Evaluate the alternatives. Various courses of action are compared in terms of personnel, material, equipment, and time. This is often difficult because the typical planning problem is filled with uncertainties and intangible factors.

Select the course of action. Planning is not yet complete with the accomplishment of the above steps. Derivative plans must be developed to support the basic plan.

THE ORGANIZING FUNCTION

The organization function determines and enumerates the activities required to complete the project, groups these activities, assigns the groups, and delegates authority to carry them out. Sometimes all this is called organization structure. The organization structure is a tool for accomplishing the project's objectives. It establishes authority relationships and provides for structural coordination. Therefore, organizing is the establishment of the structural relationships by which an enterprise is bound together and the framework in which individual efforts are coordinated.

The power of decision granted to or assumed by the supervisor or manager is authority. When the number of people involved in a project exceeds the span that one person can control, the manager must delegate authority. The delegation of authority is the key to an effective organization.

An officer making decisions also assumes responsibility and must answer for the results of decisions. Wherever authority is created, responsibility is created. Although authority may be delegated and divided, responsibility cannot be delegated or divided. No responsible officer can afford to delegate authority without designing a system of control to safeguard the responsibilities.

A manager may delegate the authority to accomplish a service, and a subordinate in turn may delegate a portion of the authority received, but these superiors do not delegate any of their responsibility. No supervisor loses responsibility by assigning a task to another.

THE STAFFING FUNCTION

Staffing is finding the right person for the job. Although the modern armed forces place much emphasis on the effective use of mechanized equipment, the military effort depends on the training, assigning, and supervising of people who use this equipment. The engineers have problems in construction, often because of limited personnel. Solutions to these problems require planning and coordination of personnel assignments.

THE DIRECTING FUNCTION

The management function of directing involves guiding and supervising subordinates to improve work methods. Open lines of communications in

organizations are maintained in vertical and horizontal directions. While assignment of tasks make organization possible, directing adds a personal relationship. Directing embraces the practical problems in getting personnel to work as a team to accomplish the unit objective. Basically, it concerns managing human behavior and taking action that will improve performance.

The commander must have a thorough knowledge of the organization's structure, the interrelation of activities and personnel, and the capabilities of the unit. In addition, the military manager must be able to lead the organization to accomplish its mission.

The manager can create the best conditions for superior effort by making certain subordinates understand the unit mission and their particular roles in it. People who "know the reason why" are better motivated. A good leader makes it a point to explain to troops the reasons for undertaking a particular mission.

The terms manager and leader are not synonymous. The manager coordinates activity by executing managerial functions and accomplishes missions through people. To this end, the manager uses leadership.

- The successful leader must have a broad perspective of duties and the ability to persuade others to cooperate.
- The leader must be mentally mature, that is having habits of logical methodology and understanding. Emotional balance is even more important.
- A leader cannot become panicky, unsure in the face of conflicting forces, or pliable under influence.
- A leader must also possess the ability to produce effective written and oral communications.

THE CONTROLLING FUNCTION

Control is a continuing process of adjusting the operation to the situation in order to accomplish the desired objective. The manager must measure and correct activities in order to compel events to conform to plans. For effective control, the manager must be in constant touch with operations to be sure they are proceeding on course and on schedule. Most of the construction control problem involves processing large volumes of technical information.

The manager must first be sure that the plans are clear, complete, and integrated. Then the necessary authority must be given to the person responsible for a task.

Principles. Because of the many changes and situations that may arise on different projects, a control system must be broad enough to cope with all possibilities. Regardless of the circumstances, control depends upon the communication of information, both for gathering data and for implementing the desired corrective action. To provide effective control, communication of information must meet the following tests:

Timeliness. In order to be meaningful, the manager must receive and distribute the information used for controlling in a timely manner. Information should be “forward looking.” Focus attention on actions that will cause activities to occur as scheduled, instead of adjusting for events in the past.

Accuracy. Pinpoint and then truthfully report the information necessary for control.

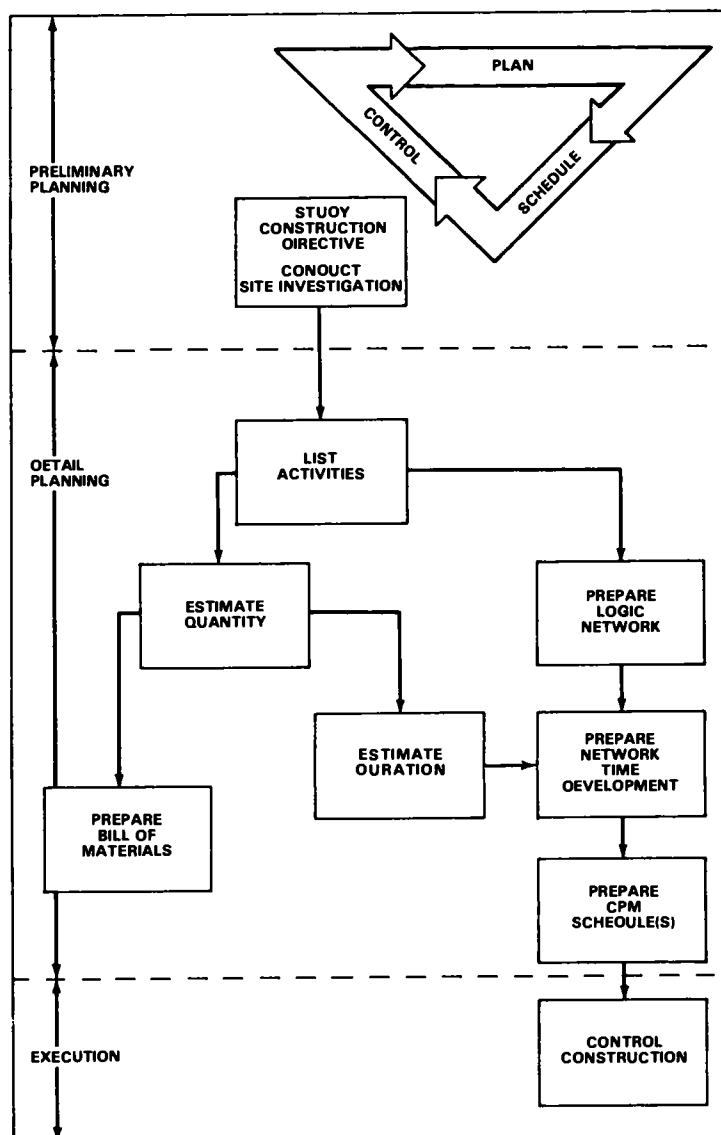
Validity. Information is valid when its content represents a situation as it actually exists. Present this information in appropriate and useful units of measure.

Routing. Make information used in controlling directly available to the person who can take or recommend corrective action, by virtue of both authority to do so and technical knowledge of the project.

Economy. Collect only the information required for effective control, thus minimizing the personnel, time, and money needed to perform the control function.

Development. The controlling process is shown in figure 1-1, on page 1-12.

FIGURE 1-1
STEPS OF THE CONTROLLING PROCESS



MILITARY CONSTRUCTION MANAGEMENT

DIFFERENCES FROM CIVILIAN PRACTICE

In a TO, construction, repair, rehabilitation, and maintenance of facilities differ considerably from ordinary civilian practice. Although the engineering principles involved are unchanged, in combat area operations the

factors of time, personnel, materials, and enemy action impose a great range of problems. This requires modification of construction methods and great concentration of effort. Engineers in a TO do not attempt permanent construction.

Management Problems. The variety of construction in the military, often done on a crash basis, creates challenging management problems. In fact, each job is unique in that the location, weather conditions, climate, soil, and possible enemy action are not quite like those of any other job. Standard designs are used, but they must be adapted to a particular site in each case. Construction materials are often less uniform than those used in the manufacturing industries. Management under these conditions involves unusual problems.

Procurement Problems. Engineer battalions normally have no authority for direct, local procurement, so materials must be provided by a senior engineer headquarters or other military or government organization. This imposes upon the Army the problems of coordination, purchase, and delivery of materials. These materials are normally procured in the United States and may require long lead times.

CHOICE OF TROOP OR CONTRACT CONSTRUCTION

The primary alternative to troop construction is the use of contractors or host nation support personnel. While nonmilitary construction is often justified, there are definite advantages to using troop construction.

Advantages of Troop Construction. First, troop construction is economical, since it eliminates the cost of labor and the contractor's profit. Second, tactical considerations frequently create a situation where contractors or host nation support personnel are unwilling or unable to undertake a project. Third, troop construction is more flexible since there are no contracts to renegotiate for changes in plans, specifications, or required availability date. Finally, peacetime projects serve as excellent training vehicles for soldiers.

Advantages of Contract Construction. A contractor may vary the number and skill level of laborers and the amount and type of equipment as a project progresses. Such flexibility is limited when using troop resources. On the basis of unit integrity, the optimum unit and the optimum amount of construction equipment for the project are selected. This method is more desirable than the task force organization (where labor and equipment are selected to fit the job) because it supports the principles of management. In addition, troop construction equipment is not as specialized as commercial equipment because it must be rugged and flexible enough to meet a variety of combat construction tasks.

Coordination of Contract Construction. When a particular TO requires extensive construction, it may demand the controlled and coordinated use

of contractors, as well as the military engineer elements of the Army, Navy, Marine Corps, and Air Force. Contract construction for the Army, in some cases, may be administered by another US military service.

CONSTRUCTION DIRECTIVE

The management process starts with the receipt of a directive which is an order to construct, rehabilitate, or maintain some facility. The directive should include a description of the project with plans and specifications. Regardless of the form of the directive or the amount of detail, the construction directive (figure 1-2) should contain the following items:

- **Mission.** The mission will state the exact assignment with all necessary detail, and may include an implied mission.
- **Location.** This may be a definite location, or the directive may require the manager to select a site in a general area.
- **Time.** The time gives the start or finish time. If responsible for planning and estimating, the manager should be the one to determine how long the project will take.
- **Personnel.** The manager should already know what personnel are available. This item tells what additional personnel are available, if needed.
- **Equipment.** The manager knows what equipment is on hand. This item details the additional equipment available, if needed to accomplish the mission.
- **Priorities.** This gives a single priority for the entire project or separate priorities for different stages of a project.
- **Reports.** This item should list reports required for control purpose to be included in the unit standing operating procedures (SOP).
- **Materials.** The directive is the authority for requisitioning materials. This item addresses the lead time necessary for procurement, location, and delivery.
- **Special Instructions.** This item gives any additional information concerning the project, including instructions for coordinating with the using agency.

FIGURE 1-2
SAMPLE CONSTRUCTION DIRECTIVE

HEADQUARTERS
111th ENGINEER BATTALION
FORT WHATITSNAME, VA 22222

26 June 1986

SUBJECT: Construction Directive No. FWV 81-002C-111

Commander, Company B

1. You will install two culverts per attached plans and specifications.
2. Location: Intersection of Range and Lewis Roads, Fort Whatitsname, Virginia. See site plan.
3. Time: Construction will begin not later than ____ 198__.
4. Additional personnel and equipment.
Additional hose is available for air compressor.
5. Priority: A
6. Reports: Submit a complete activities list for the project.
Progress reports will be submitted in accordance with SOP.
7. Materials: One hour notice is required for pickup of culverts.
8. Special Instructions: No changes are authorized except thru Battalion S-3. The contact officer for the using agency will be CPT Hamlin who can be contacted at Building 247. Telephone - 44837.

FOR THE COMMANDER:

R. U. FORREAL
CPT, CE
Adjutant

SITE INVESTIGATION

A reconnaissance should be made of the selected site, or of a general area to select a site. The manager uses this investigation to determine how the environment will affect the job to be done. A reconnaissance should provide answers to the following questions.

- What are the *terrain* features of the proposed site? Is it hilly, flat, wooded, swampy, or desert? How will it affect the project?
- What are the existing *drainage* characteristics? Is the site well drained? What effort will be needed to keep it drained before, during, and after construction?
- What problems will be involved in *accessibility*? What effort will be required to permit travel to, from, and within the site?
- What is the type of *soil*? What will have to be done to permit vehicle traffic and construction? How much additional work will have to be done to permit the project to be completed?
- Are there any *existing facilities*—buildings, roads, or utilities—that could be used to advantage?
- Are there any usable timber, water, aggregate, borrow materials or other *natural resources* located near the job site? How far away are they? How much is there?
- What *weather* conditions are expected for the project duration?
- What is the *enemy* situation? What are the good points and bad points of defending the site? What improvements must be made?

OPERATIONAL PLAN

After studying the construction directive and preparing the site investigation notes, the project manager can start preparing an operational plan. This plan should include all aspects of the project involving administration and logistics. These include, but are not limited to, the following:

- Moving onto the job site.
- Bringing in supplies and equipment.
- Locating supply, assembly, work, dining, living, and administrative areas.
- Obtaining and using natural resources.
- Performing daily routine chores.
- Providing area security in a tactical environment.

- Planning for inclement weather.

The only aspect of the project the operational plan does **not** cover is the mission itself. The manager will examine the mission when starting detailed planning for the project.

MILITARY LABOR

The manager must be aware that there are limitations on the use of military labor on peacetime projects. Regulations specify severe penalties for violations of these limitations. Therefore, it is the manager's responsibility to question a construction directive if it appears to violate any of the following limitations:

Purpose. Use of military personnel for the maintenance, repair, alteration, and new construction of real property is limited to projects that will attain and maintain technical unit proficiency, or to projects restricted by security.

Policy. Department of the Army (DA) policy prohibits the use of soldiers in competition with civilian labor when it can be avoided. Lack of funds is not a valid basis for using military personnel where not otherwise permitted.

Costs. Military labor costs are not included when determining the level to which a project must be submitted for approval. However, travel and per diem for troop labor, plus costs of maintenance and operation of government-owned equipment, will be included. The cost of unfunded military labor and equipment depreciation must be accumulated and recorded as part of total project costs.

Additions. No new work can be performed in a new facility within one year of its completion unless approved by Department of the Army. An example would be adding partitions in the orderly room.

PLANNING STAGES

In military construction, the planning phase should be divided into two stages, preliminary planning and detailed planning. These are discussed more fully in chapter 2.

Preliminary Planning. Preliminary planning gives the engineer unit commander a quick overview of the assigned task and the capacity of the constructing unit to accomplish the tasks. It serves as a guide to the detailed planning which follows. Preliminary planning includes preliminary estimate and procurement of critical items.

Detailed Planning. Detailed planning develops an accurate estimate of the materials, labor, and equipment to do each of the subtasks in a construction project and provides a schedule for the entire project. It

includes review of drawings and specifications, detailed estimating, scheduling, procurement, and construction plant layout.

AVAILABLE RESOURCES

The quantity takeoff provides the planner with a fairly accurate picture of what is to be done. The planner must now determine if the available resources will allow the constructing unit to do the job.

Personnel. A unit's personnel must be considered only in terms of "construction strength." The number of soldiers actually available to work on the job must be used. In the current combat heavy battalion table of organization and equipment (TOE 5-115H) approximately 50 percent of a full-strength unit is productive in the construction effort. This figure may or may not hold true for a particular unit and should be used for planning purposes only when more exact data are not available. The project must consider availability if it requires large numbers of personnel with particular skills (for example, plumbers or electricians). Availability must also be considered if additional personnel is authorized by the job directive.

Trained personnel. The manager must consider the training of the personnel available for the construction effort. A full strength battalion with many inadequately trained personnel will result in a low construction output.

Supervisors. The ability and number of supervisors (not included as productive personnel) affects the construction capability of a unit. A shortage of competent supervisory personnel will reduce the construction effectiveness of a unit even though the productive personnel are adequate in number and ability.

Equipment. The status of a unit's construction equipment, particularly heavy equipment, is an important factor in determining the ability to do a job. The planner must consider the average deadline rates for items of equipment and then judge whether the rates will be maintained, improved, or worsened during a particular job.

Critical items. Depending on the type of job, certain items of equipment will be critical because they will govern the overall progress of the job. For example, earthmoving equipment is critical for road and airfield work. Woodworking sets are essential for wood frame structures. Appendix E lists equipment and tools that may be needed.

Distribution. The planner should tentatively assign the critical items to the various construction operations. Assignment will depend on the amount of equipment on hand, deadline rates, and quantity and type of work to be done. For example, in assigning dozers and scrapers to cut and fill operations, the quantities of earthwork and the haul distances will determine how many of the available dozers will be assigned to the scrapers and how many will be used for dozing.

TIME ESTIMATES

The planner's next step is to estimate the time required to do the job. Extreme accuracy is not required, as detailed calculations are left for the detailed planning stage. Approximate rates of production based on the unit's experience records are accurate enough. Where this information is lacking, published rates in civilian or military texts, tempered by the planner's knowledge of existing conditions, are a good substitute.

The quantity takeoff uses available equipment and personnel to calculate the time required for each item. This time will be increased if the soldiers are inexperienced and require on-site training. Total time for the project is the sum of the times calculated less the time when two or more work items will be done concurrently. Except where detailed planning produces more accurate time data, use this overall project time for planning.

CLIMATIC CONSIDERATIONS

The effect of climate on construction operations is so great that the evaluation of this item alone can be as important as all other factors combined. If the planner fails to consider weather, more time may be lost because of bad weather than would be needed to finish all the work in favorable weather. The planner must evaluate each type of work to be done in relation to the weather conditions expected during construction. For example, for road and airfield work, it may be better to do all the clearing and stripping before starting subgrade and subbase operations. This may be done only if it is certain that there will be little or no rain during the clearing and stripping, before adequate drainage can be provided. Evaluating weather lets the planner determine how much time to allow for weather delays.

CONSTRUCTION SEQUENCE

The sequence of major operations is another factor which the manager must evaluate in the preliminary stage. In some operations like clearing and stripping, or excavating and placing footings, the sequence is obvious and does not present a problem. The manager cannot determine other sequences, such as materials processing and prefabrication, until later in the detailed planning stage. However, the manager must consider construction sequence early in the planning, because some factors such as drainage and materials affect job sequence and are present at the very beginning of planning.

Drainage. Although the anticipated weather may be almost ideal, with only slight showers expected for the duration of the project, poor existing or natural drainage might cause flooding of the construction site. Therefore, the manager must make provision for adequate drainage early in the sequence of operations.

Material Availability. Availability of materials will affect job sequence. Operations dependent upon materials cannot be started until the materials are available.

PROCUREMENT OF CRITICAL ITEMS

During the preliminary planning stage, the planner should keep notes on items that may be critical to the job. These critical items may be readily identified when using the network analysis system. Critical items may be materials, equipment, or soldiers with particular skills. Their availability may be important because they are needed immediately for the job, because they are not available locally, or because a long lead time for procurement may be required. The manager should study the entire job and the notes and tabulate such critical items. Then, the manager can take action to ensure that the items will be on hand when required.

EXECUTION

The execution phase begins with the actual start of construction although some procurement actions may already have taken place. To ensure compliance with the schedule and with the project plans and specifications, the engineer unit commander uses supervision, inspection, and progress reports. Any changes in project plans and specifications made after construction has begun involve replanning and rescheduling.



Chapter

Planning and Scheduling Processes

SYSTEMS MANAGEMENT

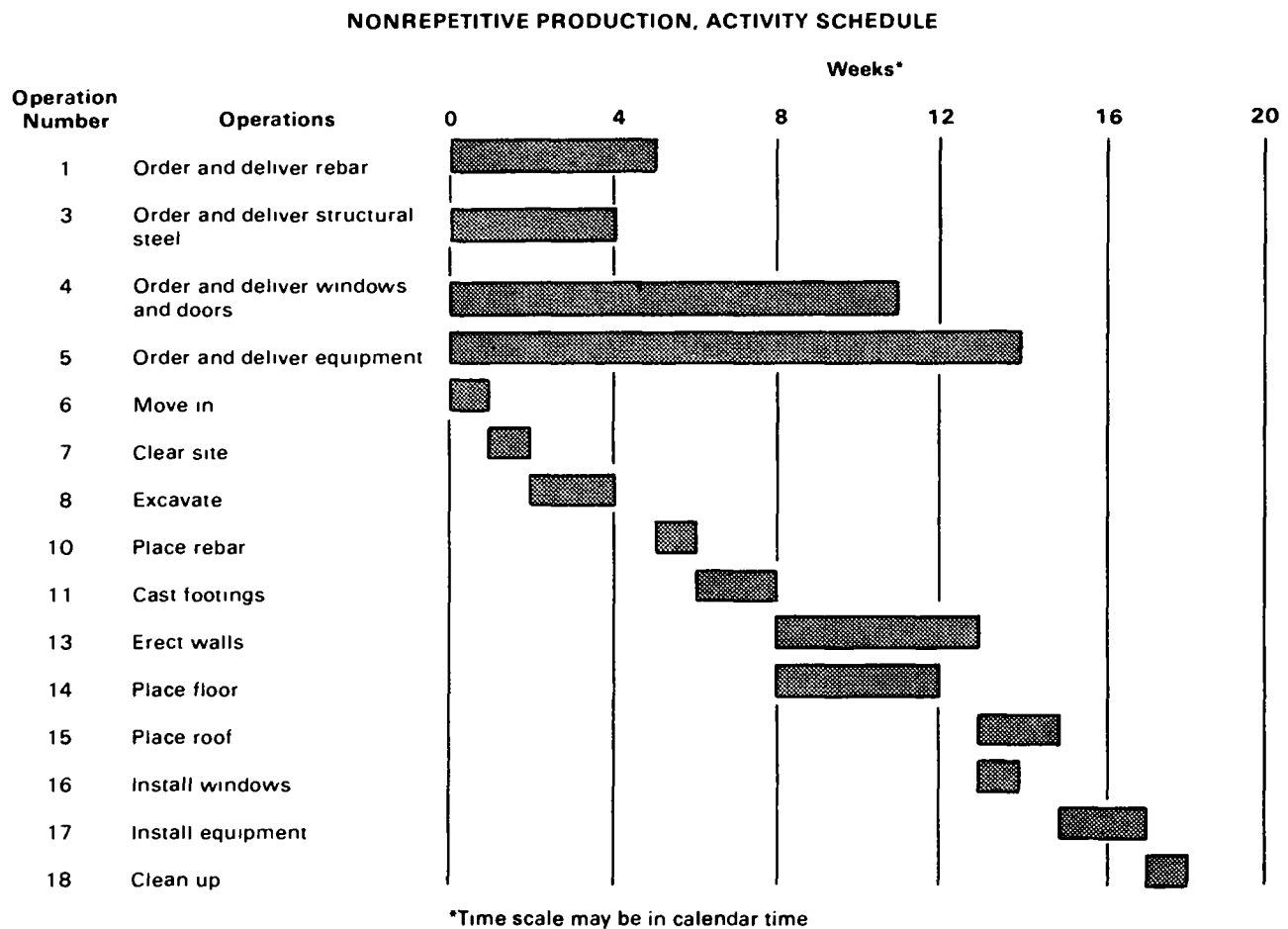
Engineer tasks must be managed whether the task is a rear area construction job such as a supply depot, or a forward area combat engineer task such as a barrier minefield. The engineer manager must use a combination of personnel, materials, and equipment to accomplish the tasks. These three resources are affected by time, availability of resources, the tactical situation, weather, and terrain conditions.

These factors affect both construction planning and combat planning. How well the engineer leader accomplishes a task depends largely on the ability to plan, schedule, and control resources within a constrained environment. This chapter describes the basic elements of systems that will aid the manager in accomplishing the mission.

GANTT CHART METHOD

An excellent means of project planning and control is the Gantt or bar chart (figure 2-1, on page 2-2). Used primarily for small projects, it is simple, concise, and easy to prepare. The major disadvantage of this management tool is that the user must have a detailed knowledge of the particular project and of construction techniques. This disadvantage can create a problem if the project manager must be replaced suddenly. The replacement is faced with a document in which all the relationships are not readily apparent.

FIGURE 2-1
GANTT CHART



Other disadvantages of planning with a Gantt chart are—

- It does not clearly show the detailed sequence of the activities.
- It does not show the relationships among the activities.
- It does not show which activities are critical or potentially critical to the successful completion of the mission on time.
- It does not show the precise effect of a delay or failure to complete an activity as planned.
- In an emergency, a failure may lead to the expediting of noncritical activities.

CRITICAL PATH METHOD

PURPOSE

A planning and control technique which overcomes the disadvantages of the Gantt chart and provides an accurate, timely, and easily understood picture of the project is the critical path method (CPM). It provides the manager more information on the project than the Gantt chart. With this additional information, it is easier to plan, schedule, and control the project. The CPM requires a formal, detailed investigation into all identifiable tasks that make up a project. This means that the manager must visualize the project from start to finish and must estimate time and resource requirements for each task.

Uses. The CPM can be used to accomplish construction and combat tasks at any level of management from the engineer brigade to the squad.

The squad leader needs to have a basic knowledge of CPM for two primary reasons.

Engineer tasks. As a member of a larger work element, the squad leader will be responsible for assigned tasks within the CPM network. This requires a better understanding of the criticality of the tasks in relation to the total project. The squad leader can anticipate future responsibilities within the project so the squad can be better prepared or trained to accomplish these tasks.

Combat tasks. A squad may be attached to a maneuver company if required by the tactical situation. The squad leader, therefore, becomes an independent manager of personnel, material, and equipment and must now plan for, schedule, and control these assets. Normally, a formal portrayal of the CPM would not be required, but the basis for CPM becomes a valuable tool for the squad leader in accomplishing combat engineer tasks.

Advantages. The critical path method—

- Reduces the risk of overlooking essential tasks and provides a blueprint for long-range planning and coordination of the project.
- Focuses the manager's attention by identifying the critical tasks.
- Generates information about the project so that the manager can make rational and timely decisions if complications develop during the project.
- Enables the manager to determine quickly what additional resources will be needed to accomplish the project and when these resources should be made available.

- Allows the manager to determine quickly what additional resources will be needed if the project must be completed earlier than originally planned.
- Provides feedback information on a finished project that lets the manager improve techniques and assures the use of resources in future projects.

Limitations. The critical path method is not a cure-all for engineer problems. It does not make decisions for the manager, nor can it contribute anything tangible to the actual construction. The CPM should be used to assist the manager in planning, scheduling, and controlling the project. Developing networks for other purposes is a waste of time and valuable personnel resources.

PRELIMINARY PLANNING

The first step in planning is to find out all the essential information concerning the project. Most of this information can be obtained from the construction directive published by the next higher headquarters for the company or battalion level.

Gather information. If the information is not there, the manager should ask for it. At the platoon and squad level, tasking is normally accomplished by oral orders. The following information is required:

- What are the project requirements to complete the *mission*?
- *Where* is it to be accomplished?
- *When* can the project start, and when must it be completed?
- Will *additional assets*—personnel and equipment—be available, and where are they?
- Where are *materials* obtained, and who transports them?
- What is the *priority* of this task in regard to priorities of other jobs?
- Who requires initiation, progress, or completion *reports*, and in what format?
- What about *other considerations* such as job-site security, and coordination with the tactical unit responsible for the job-site area with respect to movement, communications, and fire support?

Investigate site. Conduct a site investigation to determine how the actual site conditions will affect the job. Coordinate known requirements with tactical units as well as with parent support elements.

Determine needs. Check with the customer to ensure that the final facility will satisfy the needs.

DETAILED PLANNING

The manager must study the plans and specifications carefully, construct the project mentally, and break it down into its component parts. Each component is termed an activity: a resource-consuming part of the job which has a definable beginning and ending.

Gather information. The breakdown of a construction project into activities and the placing of these activities in a logical sequence require great engineering skill. The CPM planner must consult with the construction supervisor to get the required data. Experienced noncommissioned officers (NCOs) can offer valuable assistance in planning the project and developing the estimates.

Prepare an Activity List. Developing an activities list is the starting step in project management, and the one that frustrates many managers. The number and the detail of the activities on the list will vary from job to job and depend upon the intended use of the CPM network and the experience of the managers.

Once the process of mentally constructing the project has begun, the activities come to mind very easily. Keep in mind that the activities list only states what is to be done. It will not consider how the activity will be accomplished, in what order the activities will be performed, or how long it will take to complete each activity. All that is necessary at this point is to list what work must be done to complete the mission. The other problems will be addressed later, one at a time.

The following guidelines offer some assistance, but should not be regarded as strict rules.

- Break the assigned job into the separate operations or tasks necessary to complete the job successfully. The number and detail of these tasks will vary from job to job. A checklist, appendix A, contains work elements or tasks for various construction jobs.
- Include a description of the work to be performed within each activity.
- Do **not** consider time, labor, order of construction, material, or equipment. Only break the project into its component parts.
- Check the activities list for completeness and accuracy.

LOGIC DIAGRAM

One of the most important aspects of the critical path method is the logic diagram. The project is actually being constructed mentally and on paper

as the relationships between the activities are determined. A major benefit is the diagram eliminates many problems that might arise during the construction phase of the project. From the activities list the manager must determine the essential relationships between the activities. To accomplish this, the following questions should be asked for each activity:

- Can this activity start at the beginning of the project?
- What activities must be finished before this one begins? (Precedence)
- What activities may either start or finish at the same time this one does? (Concurrency)
- What activities cannot begin until this one is finished? (Succession)

The answers to these questions will form the logic for drawing a network identifying activities (tasks) in an ordered sequence. Note that planning is a distinct phase of the operation. Scheduling follows the making of the network and tabulating information.

ACTIVITIES

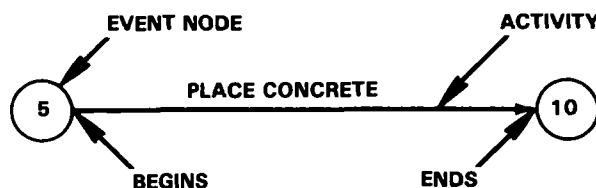
The questions of precedence, concurrency, and succession form the logic for a project network. Such a network graphically portrays relationships between activities throughout the entire project. Each activity is represented by an arrow. The tail and head represent the start and finish of the activity respectively. The activity or work flows from the tail to the head of the arrow. The length or angular direction of the arrow has no relationship at all to the time the activity requires—the arrow is not time-scaled. The way these arrows are connected shows the answers to the four questions in paragraph 2-5. When placed in a network, each arrow is labeled with the name of the activity it represents.

EVENTS

The other basic network symbol is a circle (node) which numbers the events. There are two rules for choosing event numbers. First, the event number at the head of an arrow must be greater than the event number at the tail. Second, no two event nodes in the network may have the same number. Otherwise, any numbers may be chosen for the event numbers. Once the events are numbered, there are two ways of referring to a specific activity: by its name, or by its pair of event numbers.

Thus, the activity shown in figure 2-2 could be called either “place concrete” or “activity 5 - 10.” In this manual, activity names will frequently be designated by letters, such as E, F, G, H, and I, as shown in figure 2-3.

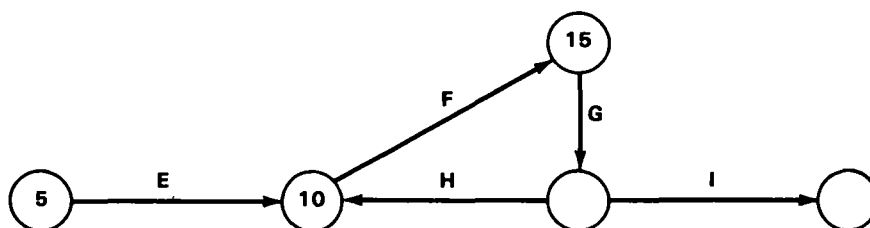
FIGURE 2-2
IDENTIFICATION OF ACTIVITY IN CPM NETWORK



There are several reasons for imposing these rules for the event numbering. One reason is to avoid confusion. Other reasons will become evident in the section on scheduling.

Figure 2-3 shows a circular deadlock. The number of the event at the head of activity G has to be greater than 15, but the number at the tail of activity H must be less than 10. The event numbering rules help prevent this kind of error, which is difficult to discover in a large network.

FIGURE 2-3
CIRCULAR LOGIC ERROR



NETWORK LOGIC

The logic behind CPM networks is that activities (arrows) leaving an event (circle) cannot begin until all of the activities entering that event have been completed. Figure 2-4, on page 2-8, shows that activity B cannot begin until activity A has been completed. It also indicates that activity G cannot start until both activities C and D have been completed, and that neither activity D nor H can start until activity I is completed. Further, activities C and D are concurrent because they end at the same event; D and H may start at the same time.

DUMMY ACTIVITIES

Suppose that a unit must build a gravel road and also place some concrete nearby. Further, suppose the unit uses the same gravel and rock for both the

road surface and the concrete. The CPM network (figure 2-5) shows that the road depends on the aggregate and the concrete mixing depends on having the cement.

FIGURE 2-4
INTERRELATION OF NUMBERED ACTIVITIES

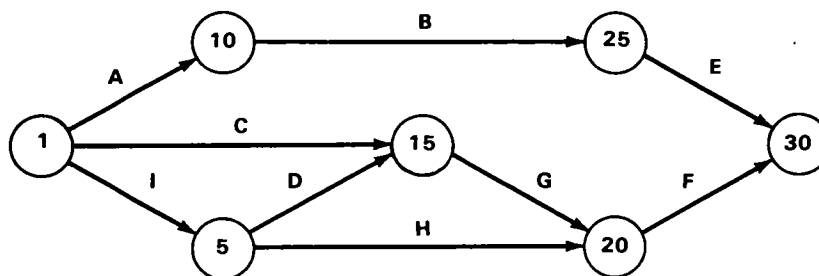
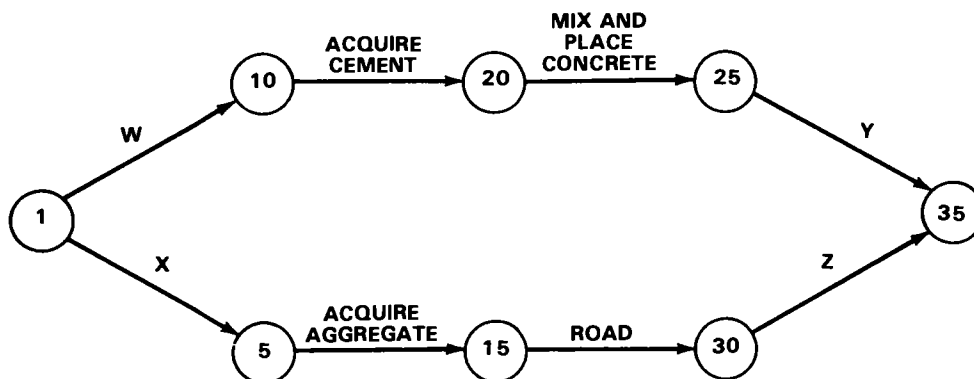


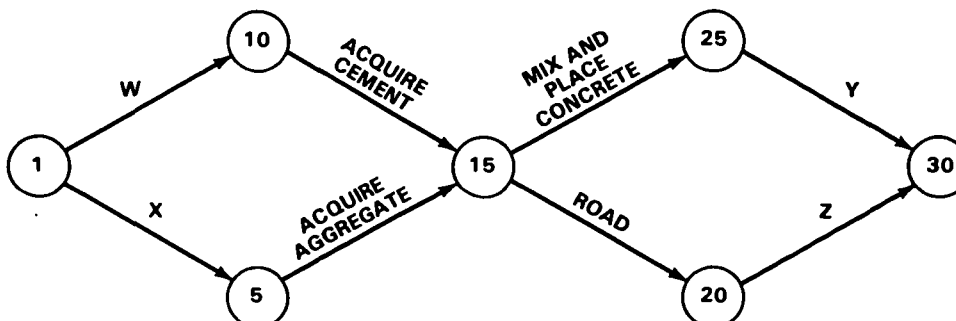
FIGURE 2-5
INITIAL NETWORK FOR ROAD AND CONCRETE PROJECT



However, the mixing of the concrete must also depend on having the aggregate. One way to show this would be to redraw the network as shown in figure 2-6.

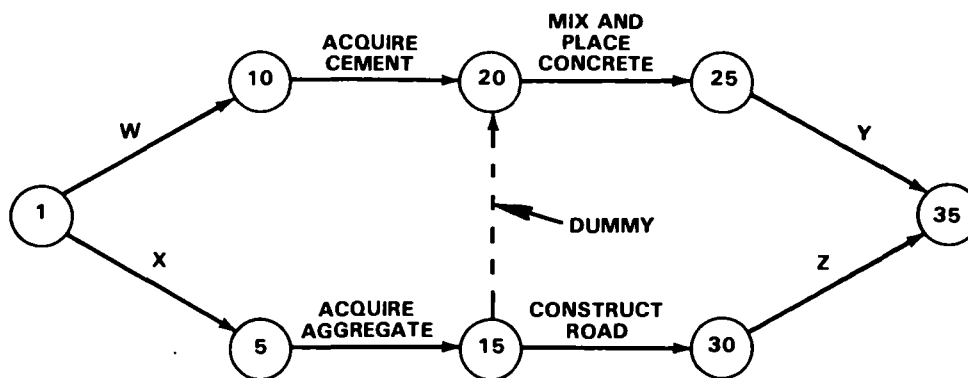
At first, the network revision shown in figure 2-6 seems like a good solution to the problem, because the network now shows that the concrete depends on both the cement and the aggregate. However, this network also indicates that the road depends not only on the aggregate, but also in the cement—which is not needed for the road. The road construction has been unnecessarily constrained.

FIGURE 2-6
FIRST REVISION OF NETWORK IN FIGURE 2-5



Dummy arrows. The way out of this difficulty is to draw another activity arrow from the end of the aggregate activity to the beginning of the concrete activity. Since this new activity arrow simply shows a sequence relationship (in this case, that concrete depends on aggregate), does not have a name, and does not represent any part of the project, it is called a dummy activity. It is represented by a dashed arrow (figure 2-7). Dummy arrows take zero time, show only relationships, and are represented with dashed rather than solid lines.

FIGURE 2-7
USE OF DUMMY ARROW



Event numbers. Dummy activities eliminate event number duplication. In figure 2-8, on page 2-10, both activities A and B can be referred to as “5-10.” In order to be identified by their event numbers, each activity must have a unique pair of these numbers. Redrawing the network and placing a dummy activity after either of the two activities gives each of the activities a unique event number identification (figure 2-9, on page 2-10).

FIGURE 2-8
DUPLICATION OF EVENT NUMBER

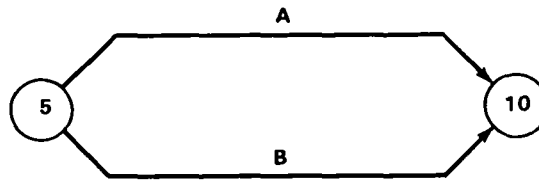
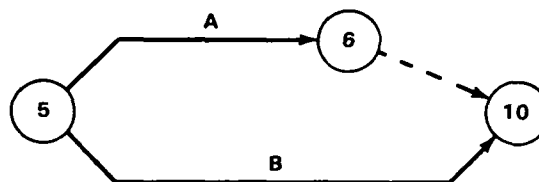


FIGURE 2-9
USE OF DUMMY TO REMEDY DUPLICATION



DURATIONS

The logic network is constructed without estimating data. It displays the relationships between activities, provides project understanding, and improves communications.

Once the network has been drawn, the manager places the durations required to complete the activities in parentheses beneath the appropriate arrows. The manager determines these times by the estimating procedure discussed in Chapter 3, Construction Estimates. This procedure is recommended as a standard because it is flexible and lends itself to full documentation.

Estimating is the lifeblood of CPM time analysis. Estimating data (durations and crew sizes) forms the basis for calculation of early and late event times and critical activities, tabulation of activity times, and scheduling. Thus, output of CPM time analysis can be no better than the estimating input. If an estimate changes because of new information or experience, the estimator must use these new data to update the time analysis. A time analysis based on outdated estimates is useless.

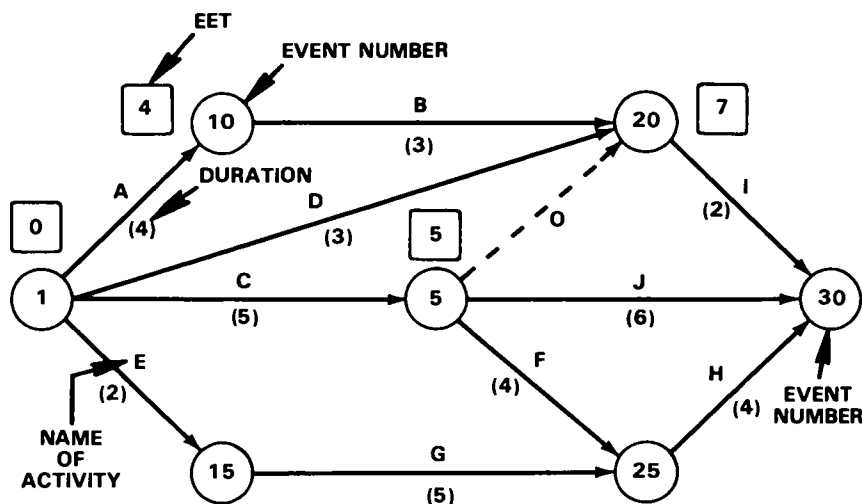
CALCULATION OF EVENT TIMES

The next step in the CPM process is to calculate the earliest and latest times at which the events can occur. An event "occurs" immediately upon completion of all of the activities going into that event. Thus, the

succeeding activities cannot start until the event has occurred. These event times represent the end of the time period. Thus, an event time of five would mean the end of the fifth day (hour, week, and so forth).

Early Event Times. First, compute the early event times (EETs). Place these times, which are the earliest times the events may occur, in small squares above or next to the event nodes. Since the beginning event represents the start of the project (figure 2-10), the earliest time that event 1 can occur is zero (the end of day zero or the beginning of day one).

FIGURE 2-10
NETWORK WITH EETS ADDED

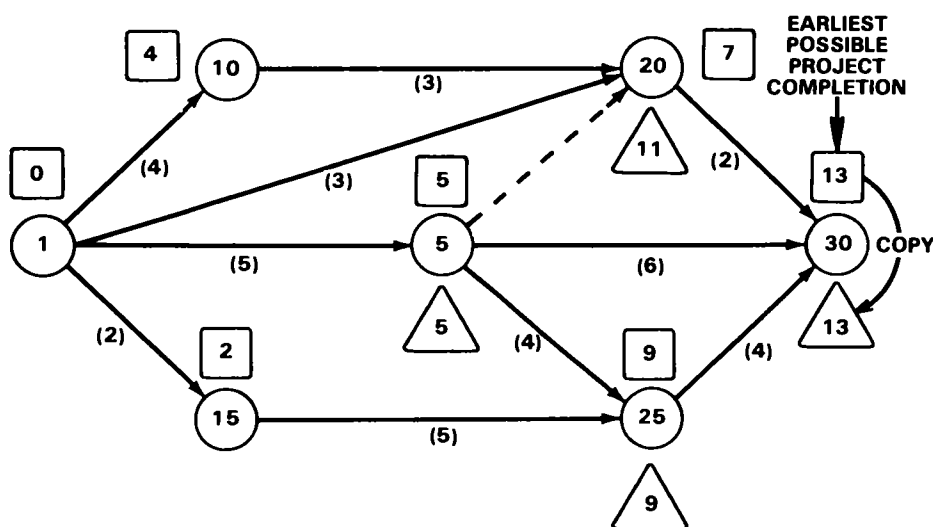


Next, trace along an activity leaving the first event to the event at its head, say event 10, adding the duration (4) to the EET at the tail of the activity (0). Thus, the EET for event 10 is 4 ($0 + 4$). Now, suppose there is more than one path going into an event, for example, event 20. Path 10 - 20 (event numbers) gives $EET(\text{event } 10) = 4 + 3 = 7$ for $EET(20)$. Path 1 - 20 gives $0 + 3 = 3$ for $EET(20)$. The dummy path 5 - 20 gives $5 + 0 = 5$ for $EET(20)$. Since an event cannot occur until all the activities going into it have been accomplished, the event cannot occur until the last activity has been finished. Thus, when there is a choice for EETs, use the largest of the choices. In the case of $EET(20)$, use 7 (larger than 3 or 5) for the EET.

Using this logic, work through the network from left to right, getting the EETs for all the event nodes. The EET for the last event is 13 and is the earliest possible time the entire project can be finished, given the sequence of construction activities and the time durations on each activity.

Late Event Times. After all of the EETs have been computed, calculate the late event times (LETs), which are written in triangles beneath the event nodes (figure 2-11). The LET for an event is the latest time that the event can occur and not delay the project beyond the earliest completion time (in the example, the end of the 13th day). Therefore, the LET for the ending event is the same time as the EET for that event.

FIGURE 2-11
NETWORK WITH LETS ADDED



To get the other LETs, work backwards from the ending event, going against the arrows. Subtract activity durations from the LET at the head of an arrow to get the LET at the tail of the arrow and disregard the EETs in this reverse pass through the network. Thus, starting from the final event, to find the LET for event 25, subtract 4 (duration of 25 - 30) from 13 (LET at event 30), getting 9 as LET (25). Suppose there are two or more choices; at event 5 there are three possibilities for the LET. Path 5 - 20 gives $LET(20) = 11 - 0$ (duration of dummy) = 11. Path 5 - 30 gives $13 - 6 = 7$, and path 5 - 25, gives $9 - 4 = 5$.

Since the project cannot be delayed, when there is a choice of LETs, choose the smallest one (in this case, 5). To understand this rule, assume that some larger time, say 6, is used. Working through the network via route 5 - 25 and 25 - 30 shows the project has been delayed one day. The last LET calculated is for the beginning event, and LET must come out zero. If the smallest is any other number (positive or negative), there has been a mistake in the calculations.

CALCULATION OF CRITICAL ACTIVITIES

A critical activity, if delayed by any amount of time, will delay the entire project's completion by an equal amount of time. All critical activities can be found from the network by applying the following three rules:

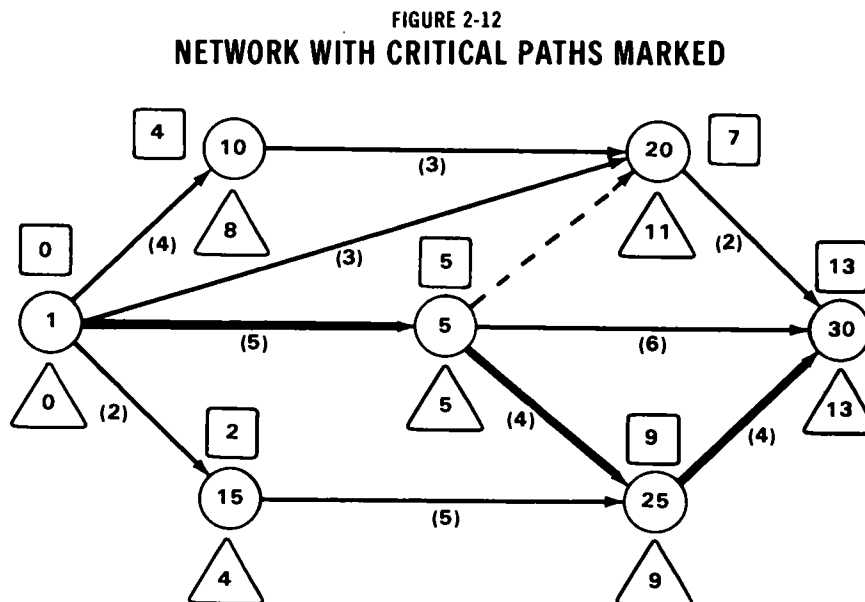
Rule 1. The EET and LET at the tail of the activity arrow are equal.

Rule 2. The EET and LET at the head of the activity arrow are equal.

Rule 3. The EET or LET at the head minus the EET or LET at the tail is equal to the duration of the activity.

In the example shown in figure 2-12, activity 1 - 10 is not critical because the event times are not equal at the head (4 is not equal to 8). Activity 5 - 30 is not critical because even though rules 1 and 2 are met, rule 3 is not met (13 - 5 is not equal to 6). Activity 5 - 25 is critical because rules 1 and 2 are met and $9 - 5 = 4$ (duration). As critical activities are found, indicate them on the network by some method such as double lines or colors. Some pointers on these critical activities are as follows:

- The critical activities form a continuous path (the critical path) from the beginning event to the ending event.
- There will always be one or more critical paths.
- Dummy activities may be critical, if they pass the three rules.



- The sum of the durations along a critical path (going with the arrows) will always be the project duration.
- If a critical path begins or ends in the middle of the network (is not continuous), a mistake has been made.

For an example of EET and LET analysis on a CPM network, see page 2-22.

TABULATION OF ACTIVITY TIMES

Once the manager has calculated the event times on the main network, the next step is to tabulate the activity times. The tabulation consists of the following:

- The activity designation (event numbers).
- The duration (DUR). This is copied directly from the network.
- The earliest time the activity can start (ES). This is the EET at the tail of the activity arrow and is copied directly from the network.
- The earliest time the activity can finish (EF). This is calculated using the formula: $EF = ES + DUR$.
- The latest time the activity can start and not delay the project (LS). This is calculated using the formula: $LS = LF - DUR$.
- The latest time the activity can be finished and not delay the project (LF). This is the LET at the head of the arrow and is copied directly from the network.
- The total float (TF).

Total Float. The total float is the scheduling leeway. Starting the activity as early as the ES, as late as the LS, or anywhere in between, will not delay the total project duration. Total float, then, is simply $LS - ES$ or $LF - EF$. All activities with zero total float are on the critical path.

Tabulation. The completed tabulation for the example network is shown in table 2-1. The equations for tabulation of the activity times are as follows:

$$ES = \square \text{ or EET at the tail of the activity arrow}$$

$$EF = ES + DUR$$

$$LS = LF - DUR$$

$$LF = \Delta \text{ or LET at the head of the activity arrow}$$

$$TF = LS - ES \text{ or } TF = LF - EF$$

TABLE 2-1
TABULATION SHEET

Activity	Duration	Early start	Early finish	Late start	Late finish	Total float
	()					
1 - 10	4	0	4	4	8	4
1 - 5	5	0	5	0	5	0*
1 - 15	2	0	2	2	4	2
1 - 20	3	0	3	8	11	8
10 - 20	3	4	7	8	11	4
5 - 20	0	5	5	11	11	6
5 - 25	4	5	9	5	9	0*
5 - 30	6	5	11	7	13	2
15 - 25	5	2	7	4	9	2
20 - 30	2	7	9	11	13	4
25 - 30	4	9	13	9	13	0*

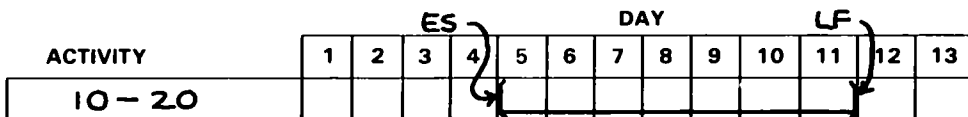
*Zero float defines a critical activity.

SCHEDULING

Now the manager can construct a schedule from the tabulation. The first step is to list all activities on the network in ascending numerical order based on beginning event node numbers. Activities with the same starting event node numbers are, in turn, listed in ascending numerical order based on ending event node numbers. Omit dummy activities and only schedule work activities. To maintain the original logic of the network, however, show where dummy arrows leave activities by placing the dummy arrow's ending node number in parentheses after each activity that it follows. After listing activity numbers, the next step is to mark on the schedule the time span during which each activity may be performed without delaying the project or violating any of the network sequence relationships.

Consider, for example, activity 10 - 20 (figure 2-12). The tabulation shows that the earliest it can start is the end of day 4. The beginning of day 5 to the end of day 11 represents the range within which the activity can be scheduled (figure 2-13). Because of the nature of the network, the activity cannot be scheduled earlier, since other activities must be completed first. It cannot be scheduled later, for that would delay the project.

FIGURE 2-13
SCHEDULE WITH TIME SPAN SHOWN



Trial Schedule. Once the lines are drawn on the schedule, the next step is to make a trial schedule, scheduling each activity as soon as possible, or at the beginning of the line. To indicate when a particular activity is scheduled, place the number of people in the crew on the line for each day in which the activity is scheduled. In this way the crew sizes can be added vertically to give total personnel requirements throughout the project duration.

For example, in activity 10 - 20, suppose an efficient crew size of two people has been chosen. To show this activity scheduled as soon as possible, place the number 2 (crew size) three times (duration) as in figure 2-14. The blank space on the line to the right of the numbers represents the total float, the distance (time) along the line on which one can place the activity and still not delay the project completion.

FIGURE 2-14
SCHEDULE WITH CREW SIZES ADDED

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
10 — 20					2	2	2						

Drawing these lines for each of the activities and scheduling them as soon as possible yields the early start schedule shown in figure 2-15. All activities are scheduled at their early start times. Since a dummy activity does not consume any resources (personnel, equipment, or time), it does not appear among the activities scheduled (see figure 2-12).

FIGURE 2-15
EARLY START SCHEDULE

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 — 5 (20)	5	5	5	5	5								
1 — 10	4	4	4	4									
1 — 15	4	4											
1 — 20	6	6	6										
5 — 25						7	7	7	7				
5 — 30						4	4	4	4	4	4		
10 — 20					2	2	2						
15 — 25			3	3	3	3	3						
20 — 30								5	5				
25 — 30										8	8	8	8

Sample Schedules. Notice that due to the nature of float, activities such as 10 - 20 can be scheduled in several ways without delaying the project completion (figure 2-16). However, the movement of an activity along its line could interfere with or delay some other noncritical activity.

FIGURE 2-16
THREE WAYS OF SCHEDULING ACTIVITY 10-20

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
10 — 20					2	2	2						

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
10 — 20							2	2	2				

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
10 — 20									2	2	2		

Reschedules. Suppose activity 1 - 20 is scheduled to begin at the start of day 5. The network (figure 2-12) shows that activity 20 - 30 may not start until 1 - 20 has been finished. In this case, this relationship has not been violated (figure 2-17). If 1 - 20 is scheduled to start at the beginning of day 6 (figure 2-18, on page 2-18), 20 - 30 is scheduled to start before 1 - 20 has been finished, violating network sequence logic (figure 2-12). Keeping 1 - 20 where it is, the solution is to reschedule 20 - 30 to begin on or after the beginning of day 9 (figure 2-19, on page 2-18).

FIGURE 2-17
SCHEDULE OBSERVING NETWORK SEQUENCE LOGIC

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 — 20					6	6	6						
20 — 30								5	5				

FIGURE 2-18
SCHEDULE VIOLATING NETWORK SEQUENCE LOGIC

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 - 20						6	6	6					
20 - 30								5	5				

FIGURE 2-19
RESCHEDULING OF FIGURE 2-18 TO REMOVE VIOLATION

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 - 20						6	6	6					
20 - 30									5	5			

Free and Interfering Floats. The preceding example shows that in moving activity 1 - 20, nothing was interfered with until the last scheduled workday when 1 - 20 moved into the 8th day. The total float, then, can be divided into two parts:

- Free float, which the activity is free to move into without interfering with another activity.
- Interfering float, which, if moved into, will interfere with the start of another activity.

Usually, it is desirable to use Xs to indicate the interfering float on the early start schedule (figure 2-20).

FIGURE 2-20
SCHEDULE WITH INTERFERING FLOAT MARKED

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 - 20	6	6	6					X	X	X	X		
20 - 30								5	5				

Interference. Until this point, the manager has found the activities that might be interfered with have been found by referring to the original network. This is how it was discovered that 20 - 30 depended on 1 - 20. A simpler method uses the sequence logic of the network. Since activity 20 - 30 is an arrow that goes out of event circle 20 and 1 - 20 is an arrow going into event circle 20, the sequence relationships can be deduced from the numbering system alone.

Redrawn Schedules. In addition to determining the sequence from the event numbers, it is possible to redraw the same network (although it may look different) just by knowing the event numbers for the various activities. Because dummies take no time, they are not scheduled.

If for some reason activity 1 - 5 had to be delayed, 5 - 25 and 5 - 30 might be delayed due to the delay of 1 - 5. However, 20 - 30 is also affected because of dummy 5 - 20 (figure 2-21). This relationship is shown by adding a third number to activity 1 - 5, changing it to 1 - 5 (20). Thus, if 1 - 5 (20) is shifted, check all activities beginning in 5 and 20 in the schedule. Activity 20 - 30 cannot start until all activities ending in both 5 and 20 have been completed.

Final Schedule. Figure 2-21 is now a complete early start or first try schedule. Crew sizes have been added vertically to give the personnel requirements throughout the project for this particular schedule. Using the floats, the manager works from this schedule to devise a final schedule which meets all time and personnel considerations.

FIGURE 2-21
EARLY START SCHEDULE WITH CREW SHOWN

ACTIVITY	DAY												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1 - 5 (20)	5	5	5	5	5								
1 - 10	4	4	4	4	X	X	X	X					
1 - 15	4	4	X	X									
1 - 20	6	6	6					X	X	X	X		
5 - 25						7	7	7	7				
5 - 30						4	4	4	4	4	4		
10 - 20					2	2	2	X	X	X	X		
15 - 25			3	3	3	3	3						
20 - 30								5	5				
25 - 30										8	8	8	8
TOTAL (CREW)	19	19	18	12	10	16	16	16	16	12	12	8	8

MULTIPLE-RESOURCE SCHEDULING

If a project requires different kinds of skilled labor and/or equipment, the manager can construct a multiple-resource schedule. Figure 2-23 is a multiple-resource schedule for the installation of two culverts based on the network shown in figure 2-22.

FIGURE 2-22
MULTIPLE-RESOURCE SCHEDULE

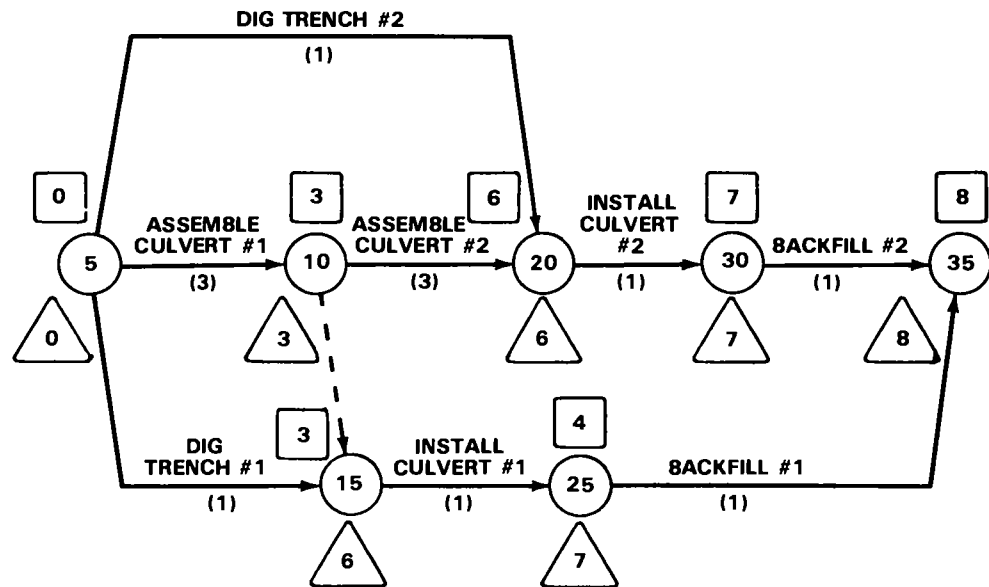


FIGURE 2-23
NETWORK FOR CULVERT INSTALLATION

ACT. NO.	DESCRIPTION	1	2	3	4	5	6	7	8	9	10	11	12	13
S-10 (15)	ASSEMBLE CULVERT #1	4	4	4										
S-15	DIG TRENCH #1	$\frac{18H}{2}$			X	X	X							
S-20	DIG TRENCH #2		$\frac{18H}{2}$											
10-20	ASSEMBLE CULVERT #2				4	4	4							
15-25	INSTALL CULVERT #1				8	X	X	X						
20-30	INSTALL CULVERT #2							8						
25-35	BACKFILL #1					$\frac{1FL}{3}$								
30-35	BACKFILL #2								$\frac{1FL}{3}$					
	RESOURCES:													
	BACKHOE	1	1											
	CREW	6	6	4	12	7	4	8	3					
	FRONT LOADER					1			1					

KEY: 8H = BACKHOE KEY: FL = FRONT LOADER

REDUCTION OF THE PROJECT

If the project duration as determined by CPM exceeds the project completion date, the manager should examine the network's critical path to find activity durations which may be shortened. Keep in mind, however, that to shorten the project duration, attention must be focused on the critical path. Shortening a noncritical activity will not shorten the project duration. However, increasing the allocation of resources to activities which fall on the critical path will reduce the duration of the project. Additional equipment and personnel can be committed, or the same equipment and personnel can be used for longer hours.

Materials. Committing additional materials may also reduce a project's duration. For example, using individual sets of forms in constructing concrete slabs is faster than reusing forms. A construction agency might expedite material deliveries by providing its own transportation. After a critical path activity is reduced by one time unit, the network must be checked to determine whether or not additional paths have become critical.

Cost. If the estimates used in the CPM network reflect the most efficient methods of construction, reducing the project below the duration determined by CPM will always cost money. In order to reduce project duration, the estimator must first identify how much each activity can be reduced in time and how much this reduction will cost. Then, through successive reductions in the duration of the critical path(s), the project is expedited at the least additional cost.

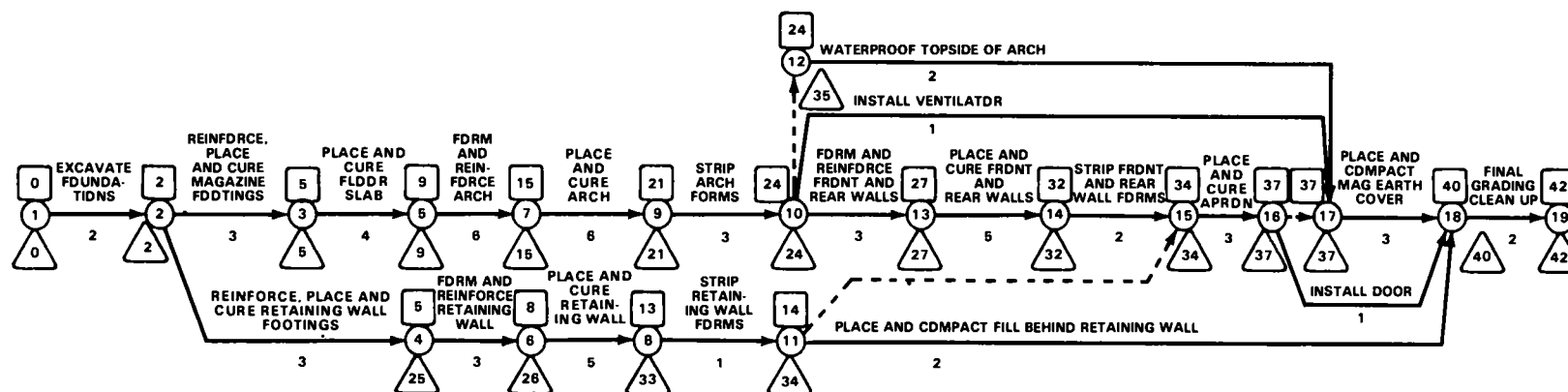
USE OF THE COMPUTER

Engineering skill is required to break a project down into an activities list, construct a logic network, and estimate activity durations and crew sizes. Once these steps are completed, the rest of CPM (including the tabulation sheet, CPM schedule, and resource balancing) can be done by computer. With further estimating data, project expediting can also be done by computer. The computer is significantly faster than manual computations for time analysis of any network with over 50 activities. CPM updating and reporting are also much easier by computer. Before undertaking the critical path method, investigate the availability of a computer with CPM programs.

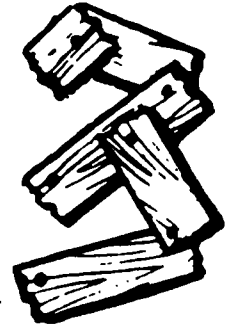
CPM NETWORK

An example of a CPM network with early and late event times for a high explosive magazine is shown in figure 2-24, on page 2-22. See appendix B, Trends in Network Analysis, for additional information on the CPM network.

FIGURE 2-24



Chapter



Construction Estimates

IMPORTANCE OF DETAILED ESTIMATES

One of the most important steps in planning a construction project is estimating. Carelessly made estimates may lead to failure to meet completion dates. They may cause uneconomical use of personnel, materials, time, and equipment; and they may seriously jeopardize a tactical or strategic situation. Preliminary estimates yield approximate data for planning purposes. They are not exact for the execution of construction tasks of any large size or complexity. More accurate, detailed estimates are vital to the successful planning and execution of a construction mission. Succeeding steps in detailed planning depend upon valid estimates. For these reasons, the military construction manager should be a good estimator and must have competent estimators in the organization.

THE ESTIMATING PROCESS

Estimating procedures are designed to yield various results. Initially, these results take the form of material requirements or bills of materials (BOM) and equipment/personnel requirements. Ultimately, the manager can derive an estimate of the time needed to accomplish each of the tasks in a project. The following paragraphs detail a sequential procedure to aid the estimator.

Materials Estimates.

Step 1. *Work items.* Determine the work items. These should agree with the CPM activities list, except where a more detailed breakdown is required for accuracy and completeness.

Step 2. *Materials.* Decide the materials required for a given work item. Study the plans and specifications in detail to ensure that all necessary materials are included.

Step 3. *Quantities.* Calculate the quantity of each item of material needed in the work item.

Step 4. *Waste factors.* Apply a waste factor, if appropriate, to each of the materials required. The waste factor should reflect conditions at the work site, intended use of the material, and skill level of the troops working with the material. Include spillage, breakage, cutting waste, and spoilage in the waste factor. Typical waste factors are in appendix C. Investigate any unusually high waste factor to determine if any action can be taken to reduce it.

Step 5. *Total material requirement.* Combine the originally calculated quantity and the allowance for waste to give the total material required.

Step 6. *Bill of materials.* Draw up a consolidated bill of materials (BOM) by combining like materials from all the work items to obtain a grand total for each type of material needed. This BOM should contain all the materials necessary to complete the job. The BOM is submitted through the appropriate supply channels for procurement.

Equipment/Personnel Estimates.

Step 1. *Work items.* List the work items to be estimated. In most cases, these will be the work items used in the material estimate, although additional activities which require workers or equipment without expending materials may be added.

Step 2. *Available resources and construction methods.* Consider available resources and methods of construction to decide how the work component should be accomplished. Describe the method of construction including sketches (as required) to provide guidance for the supervisor. If the method of construction is different from the method the work rate is based upon, adjust for this difference.

Step 3. *Material usage.* From the material estimate, determine the quantity of material which will be handled. This material estimate usually includes a waste factor. However, since the purpose here is to apply a work rate to the quantity of material handled, accuracy in determining how much of the material will be used at the specified work rate is important. For example, if the work rate for setting forms is given in terms of linear feet of formwork per unit of time and if extra form material has been ordered as waste, the extra form material should be omitted from this calculation. The amount of forms to be set is determined by the configuration of the concrete structure rather than by the quantity of material ordered. Even if the waste allowance

is used, it most likely will be used to replace broken, rotten or lost wood and thus not add to the linear feet of formwork actually set.

Step 4. *Work rate.* Select a work rate appropriate for the work item being estimated. Chapters 6 through 17 provide estimating tables for various construction tasks. Estimates given in these chapters are based on units deployed as combat support service or category III units and therefore should be adjusted for operation in other categories. (See AR 570-2 for additional information.) The TM 5-304 provides an indicator of adjustments to estimates for the environmental factor. If the information in these tables is inadequate, consult other sources such as other Army manuals, civilian texts, experience, and unit records. An accurate work rate is the heart of a good estimate.

Step 5. *Labor.* Calculate the effort required to accomplish the work item. If the work rate has been given in the usual form of man-hours (the amount of effort produced by one person working for one hour) or man-days per unit of quantity, multiply the quantity from step (3) by the work rate to get total man-hours or man-days for the task. When a work rate is presented in any other form, the planner should first convert to effort per unit of quantity.

Step 6. *Efficiency factor.* Decide whether the unit or organization can operate at the work rate given. If the work rate used in the estimate has been taken from a standard source, expect variations in local construction conditions. To compensate for this, apply an efficiency factor. This factor is a measure of the effectiveness of the troops in their situation compared to the standard conditions used in the estimating reference source. It is most commonly given as a percentage.

Step 7. *Total labor hours.* Divide the effort computed in step (5) by the workforce efficiency. Thus, if the standard effort originally calculated was 60 man-hours and the unit operates at 80 percent efficiency, the unit will have to expend 75 man-hours to complete the task.

Step 8. *Project duration.* Divide the total effort by the crew size to obtain the duration. The crew must be capable of operating at the efficiency used in the estimate. If not, the efficiency factor must be readjusted, changing the total effort and affecting the duration.

WORKSHEET ESTIMATES

Figure 3-1, on page 3-4, shows a sample format for estimating worksheets based on the guidance given in this chapter. While the format shown is not standard, it can be helpful as a guideline for estimating material, man-hours, and equipment. The situation shown requires the excavation of a rectangular ditch 60 feet long, 3 feet wide, and 4 feet deep. The work is to be done by hand; construction troops are in good condition, operating at 90 percent efficiency.

FIGURE 3-1
ESTIMATE SHEET

PROJECT: _____										ACTIVITY ESTIMATE SHEET									
ACTIVITY DESCRIPTION: <i>EXCAVATE TRENCH BY HAND, NO SHORING INCLUDED</i>																			
MATERIALS TAKE-OFF																			
MATERIAL		COMPUTATIONS								QUANTITY		WASTE		TOT QUANT		REMARKS			
MEDIUM EARTH		$60' \times 3' \times 4' \times \frac{1}{27} \text{ CY} = \frac{720}{27} \text{ CY} = 26.7 \text{ CUBIC YARDS}$																	
										26.7		N/A		26.7		~ 27 CY			
EQUIPMENT—MANPOWER																			
COMPONENT		TECHNOLOGY		QUANTITY		WORK RATE		STD EFFORT		EFF		TRF EFFORT		CREW		DUR		REMARKS	
EXCAVATE TRENCH		USE GENERAL LABOR WITH HAND TOOLS		27 CY		1.75 ^{MH} /CY		47.3 MH		90%		52.5 MH		4		13.2 H		WORK RATE FR	
																		UNIT RECORDS	
																		EFF REDUCED	
																		FOR HIGH	
																		TEMP (90°)	
SKILLS		EQUIPMENT OPERATORS		EQUIPMENT															
Supervisors —		Truck —		Trucks —															
Carpenters —		Dozer —		Dozers —															
Plumbers —		Scraper —		Scrapers —															
Electricians —		Grader —		Graders —															
General Labor <u>4</u>		Crane —		Cranes —															
Masons —		Mixer —		Mixers —															
Painters —		Roller —		Rollers —															

OPTIMUM LUMBER LENGTH CALCULATIONS

Lumber is ordered by standard commercial lengths. The lengths available in engineer depots range from 8 feet to 20 feet, in 2-foot increments. Always try to order the shorter 8-foot, 10-foot, and 12-foot standard lengths most commonly used in the military.

Length Calculation. In many parts of a TO building it is obvious what commercial lengths should be ordered. For example, if the joists and girders are 10 feet, 0 inches long, 10-foot commercial lengths are obviously needed. There are places in the building, however, where it is not quite as evident what length should be ordered. The manager must then calculate the most economical standard length for the least waste. The procedure for this is as follows:

Number pieces/standard lengths. Calculate the number of pieces per standard length for each of the three standard lengths (8, 10, 12). If this number is not an integer, round down.

$$\text{Number pieces/standard length} = \frac{\text{one standard length (inches)}}{\text{length of one piece (inches)}}$$

Number standard lengths required. Find the number of standard lengths required for each of the three alternatives. If this number is not an integer, round up.

$$\text{Number of standard lengths} = \frac{\text{number of pieces required}}{\text{number pieces/standard length}}$$

Total linear feet required. Calculate the total linear feet required for each of the three standard lengths and use the least.

$$\text{Linear feet} = \text{one standard length (feet)} \\ \times \text{number of standard lengths}$$

Sample Problem. 50 pieces of 2 inch by 4 inch lumber, 27 inches long, are required. Find the most economical length and the number of pieces to be ordered. There are three standard lengths which can be ordered: 8 foot, 10 foot, or 12 foot. The following analysis examines each.

Number pieces/standard length.

$$8 \text{ feet} = 96 \text{ inches} — 96/27 = 3+$$

$$10 \text{ feet} = 120 \text{ inches} — 120/27 = 4+$$

$$12 \text{ feet} = 144 \text{ inches} — 144/27 = 5+$$

Thus, from each 96-inch length we could get three pieces; from each 120-inch length, four pieces; and from each 144-inch length, five pieces.

Number standard lengths required.

$$8 \text{ feet} — 50/3 = 16+$$

$$10 \text{ feet} — 50/4 = 12+$$

$$12 \text{ feet} — 50/5 = 10$$

Using 96-inch lengths we must order 17 pieces. Lengths of 120 inches will require 13 pieces and 144-inch lengths will require 10 pieces.

Total linear feet required.

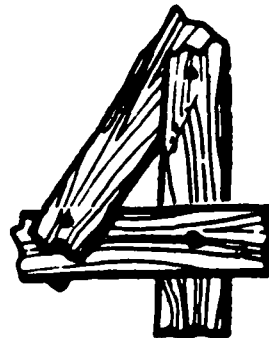
8 feet — 17 x 8 feet = 136 linear feet

10 feet — 13 x 10 feet = 130 linear feet

12 feet — 10 x 12 feet = 120 linear feet

Clearly, 12-foot standard lengths result in the minimum amount of lumber required, and 10 of these 12-foot lengths should be ordered.

Chapter



Efficient Site Layout

PRINCIPLES

IMPORTANCE

Site layout is the arrangement of the facilities and personnel required to carry out a project. It is one of the most important phases of construction engineering. The objective is to plan the physical arrangement of the site so that the construction process is carried out as efficiently as possible. This means a minimum movement of materials, equipment and personnel, and a minimum of processing time for any individual item.

This chapter presents three approaches to the site layout—systems analysis, time-motion studies, and methods engineering. The three approaches can be used separately or in combinations to gain efficiency in the site arrangement of any construction project. However, site layout analysis is essential for batch plants, quarries, borrow pits, prefabrication yards, and materials handling areas.

RESPONSIBILITIES

By custom, the first-line supervisor is responsible for efficient site layout. However, this supervisor is often too involved in the day-to-day operation of the project to be able to step back and look at the overall arrangement of the site. Also, the supervisor may have a routine way of doing a job which may not be the most efficient for a particular construction environment. Battalion and company operations officers are in the best position to provide site layout analysis for construction projects under their control. This analysis should be made available to the construction unit both in the project-planning phase and during construction.

INFLUENCING FACTORS

Many factors will influence site layout. Four important considerations are required facilities, topography, project size, and construction aids.

Required Facilities. The manager should make a list of all facilities necessary to support the work site. This list should include in-place equipment, storage areas, maintenance areas, motor pools, first aid stations, latrines, dining facilities, water points, billeting areas, work areas, control centers, and security positions. Since the effort required to plan and construct the site must be deducted from total construction effort, the site should be the absolute minimum required for efficiency.

Topography. Two identical construction projects may have entirely different physical configurations because of differing topographical conditions. The manager must incorporate the eight site factors listed in chapter 1 into any site layout analysis. The following examples show how site factors influence site layout:

Existing facilities. Existing facilities, such as utilities lines or buildings, may determine the location of critical items.

Terrain. Terrain will be a major factor in the layout of horizontal construction. If possible, locate borrow pits and quarries so that the grade favors the load (empty, going uphill; full, going downhill).

Drainage. Drainage is a crucial element in any layout. Design the site so that normal runoffs will not halt construction or transportation. Providing adequate drainage may involve considerable construction effort. The supervisor must decide at what point the cost of additional drainage structures becomes greater than the risk of flooding.

Project Size. The site for construction of one TO building will look a great deal different from the site for construction of 50 buildings. The larger the job, the greater the opportunity to take advantage of specialization. The longer the construction unit plans to remain on a project site, the greater the initial effort in preparing the site. For example, it would not be economical to upgrade a haul road to a borrow pit to be used for only a few days. It would be economical if this pit is to be used for several weeks. The construction site is generally not included in the plans and specifications of the project.

Construction Aids. Any device or apparatus installed to facilitate construction is a construction aid. Loading traps and jigs or templates for timber or steel fabrication are typical. To be practical, a construction aid must save more time than is required to establish and remove it. For example, suppose a troop camp is being built using standard theater of operations construction and involving the fabrication of 2,180 identical roof trusses. A decision must be reached as to how the truss will be made—prefabricated at a central mill, or cut and assembled individually at each building. Each truss will take an estimated 1.5 man-hours to build at a

central mill and 2.0 man-hours to build individually at the building site. The time saved is $2,180 \times 0.5$, or 1,090 man-hours. If fewer than 1,090 man-hours are needed to set up and dismantle the central truss-fabricating mill, its construction is justified. If more hours are required, its construction is not justified. An aid that is efficient on one job is not necessarily efficient on another.

PREFABRICATION

Modern prefabrication techniques may have several advantages over on-site construction: factory assembly, interchangeability of components, and labor savings. Some prefabrication is used in most construction. It ranges from the use of precut structural parts and fastenings to off-site assembly of building sections. How much prefabrication is practical depends upon several factors. The manager must consider site convenience, climate, centralized management, scale and physical nature of the project, and program flexibility. Within each of these areas, however, there are variations. For that reason, labor savings and estimates of other advantages of prefabrication cannot be precisely calculated. However, the estimator should have a good understanding of the advantages of prefabrication in order to decide when its use would be practical.

Factory Assembly. Working in factories reduces loss of time due to bad weather and other physical hazards. Quality control is easier through the use of more complex machinery and concentrated facilities. Storage security allows greater quantities of materials to be ordered and assembled in lots. Working conditions are usually better than those in the field and the resulting morale may increase efficiency.

Disadvantages are the need to construct the factory and any difficulty in making last-minute changes at the construction site. Also, transportation costs are doubled if raw materials must travel to a distant factory before they are ready for the construction site.

Component Interchangeability. With interchangeable components, many types of structures can be built from the same components, but design flexibility is limited. Structural components may be either precut pieces, frames, sheathed panels, or finished building sections. Partial assemblies may be stored for future needs. Larger parts reduce fitting errors at the site and simplify scheduling, as fewer steps are involved in final construction. However, savings may be offset by greater difficulty in joining sections and higher transportation costs for these fragile units. Interchangeability requires modular coordination, and it often requires greater skill to assure precision in subsequent fitting.

Labor Savings. The major reasons for prefabricated construction are reduced construction time and use of general instead of skilled labor. Designs involving platform construction, panel, and/or modular components allow for maximum utilization of prefabrication. Establishing a

prefabrication yard requires highly skilled personnel and may involve several days' effort, but efficient layout and organization of personnel will offset this work. Laying out the yard to minimize the distances that materials have to be carried will have a tremendous effect on the duration of the project. Once into the prefabrication process, most of the work can be accomplished by general labor or local personnel. The degree of substitution is dependent on breaking the operation down into simple and repetitive motions. At the building site the use of prefabricated components will also greatly reduce the effort involved in erection.

METHODS

SYSTEMS ANALYSIS

The first approach which could be used in a layout problem is the systems analysis approach. This method consists of the following steps (see table 4-1 for the systems analysis worksheet).

TABLE 4-1
SYSTEMS ANALYSIS WORKSHEET

Industrial Site Configuration

Design factor	Weight (1 to 10)	Evaluation (-5 to +5)	Score
Traffic flow	8	-2	- 16
Earthwork required	7	-1	- 7
Wind effects	4	+2	+ 8
Drainage	10	+5	+ 50
Maintenance accessibility	6	+4	+ 24
Product accessibility	9	+2	+ 18
Headwalls required	3	-3	- 9
Materials handling	6	-2	- 12
Stockpile areas	5	0	0
Generator location	2	-1	- 2
Conveyors required	7	+1	+ 7
		(+) Sub-Total	+107
		(-) Sub-Total	- 46
		Total	61

List the design factors to be considered for the layout. Assign a weight to each factor depending on its importance to the project.

Obtain a large-scale map of the site (1:1,000 or larger). It should show contours, natural resources, and existing facilities.

List the facilities required for the project. For each facility make a cutout to the same scale as the map.

Place the cutouts on the map in several different feasible configurations. There is no set number of arrangements which must be considered, but taking three to five to start is a good rule of thumb.

For each configuration, assign a number evaluation for each design factor based on the configuration's relative strengths and weaknesses. For example, one configuration may be best for drainage (+5 on the scale in table 4-1), but weak on traffic flow (-2). Another configuration may have opposite ratings.

Multiply factor weights by the evaluations and sum scores for each configuration. Using the configuration with the highest total, try to improve the total by making minor locational changes.

This systems analysis approach does not eliminate engineering judgment. Listing and weighting design factors require experience and engineering skill, as does the evaluation of the various site configurations. However, systems analysis does provide a framework for discussion. Using systems analysis, site layout analysts can at least agree on the points in which they disagreed. Systems analysis allows the planner to focus on specific problem areas, to gather more data if necessary, and finally to make a decision based on analysis rather than on intuition.

TIME-MOTION STUDIES

Once a project is under way, one of the most valuable pieces of equipment to the site layout analyst is the stopwatch. For any repetitive process the analyst asks the question, "Can it be done better?" Thus, time-motion improvements increase efficiency by saving time and effort. Time-motion studies are easy to do, although it takes ingenuity to see changes which would improve routine processes.

First, the analyst finds a job that is being done over and over again. This could be a crane shovel operation, a haul, a paving operation, the assembly of a wall panel, or a standard maintenance procedure. Then, the analyst times the job, noting lost time due to delays or excessive movements from one place to another. Finally, the analyst suggests ways to eliminate delays or excess movements, and then retimes the new procedure. Time-motion studies can result in increased efficiency through such specific improvements as reducing the swing angle of a crane shovel, eliminating the backing up of dump trucks, coordinating the pusher-dozer with the scraper, coordinating one apprentice with several bricklayers, and rearranging storage areas to reduce average movement distances.

METHODS ENGINEERING

Methods engineering enables the planner to make a step-by-step approach, analyzing and recording every detail involved. At the same time, the planner is able to sketch a layout plan that incorporates and conforms to the process as it is developed. When it is time to place this plan into operation, the person charged with setting up the site will know exactly what to do. Furthermore, after the operation is under way, the entire process should be analyzed in detail to determine whether further refinements can be made.

Charts and Diagrams. Three charts or diagrams have been developed which simplify the planning process. They are commonly called flow diagrams, flow process charts, and layout plans, each designed for a specific purpose. The flow diagram enables the planner to plot the flow of materials through the site. On the flow process chart, the planner details the processing of each type of material, indicating what takes place, the time required, and how far the material must be moved. The machines used are each considered in the same way as the workers. The layout plan shows the placement of equipment and materials to do a particular job.

Standard Symbols. Standard symbols, approved by the American Society of Mechanical Engineers (ASME), are used to identify what is to occur in each step of a process (figure 4-1). These steps are operations, transportations, inspections, delays, and storages. Identifying process steps in this manner helps the planner determine unnecessary steps, and the physical changes in materials.

FIGURE 4-1
SYMBOLS USED IN A FLOW DIAGRAM

DEFINITION	SYMBOL	UTILIZATION	EXAMPLE
"DO" OPERATIONS, OR MAIN STEPS IN A PROCESS		OPERATION	CUTTING WOOD, DIGGING A DITCH OR POSITIONING A PART
AN OPERATION WHICH CHANGES THE SHAPE OF THE MATERIAL		OPERATION	MAKING A CUT IN A BOARD
MOVEMENT OF MATERIAL FROM ONE PLACE TO ANOTHER		TRANSPORTATION	CARRYING A TRUSS OR A UNIT
VERIFIES QUALITY, QUANTITY, OR APPROVAL		INSPECTION	CHECKING A CENTER LINE OR TESTING EQUIPMENT
DELAY, AWAITING COMPLETION OF AN INTERRELATED JOB		DELAY	AWAITING USE
KEEP		STORAGE	MATERIAL IN STORAGE

FLOW DIAGRAM—THE FIRST STEP

The flow diagram follows the flow of materials through a sequence of operations. It helps the planner visualize and analyze the overall project. First, the planner determines the operational details of the job by considering the major steps required to process the various materials into the finished product. The objective is to determine an overall processing system with the least number of major steps, delays, and movements of

material. This is the purpose of the flow diagram. When completed, the diagram will show the flow of materials through the plant as they are processed into the finished product.

Preparation. In preparing this diagram, the planner first lists all the major steps in successive order down the left side of the form. Next, the planner details what takes place by drawing the appropriate symbols (figure 4-1) within each major step and then connecting all symbols by a single flow line.

Example.

Flow diagram using one saw. Figure 4-2, on page 4-8, shows a complete flow diagram in which only one power saw is used for cutting the members needed to fabricate the truss shown in figure 4-3, on page 4-9. In processing rafters, for example, after the plumb and tail cuts are made (same angle), the material must be stacked to one side until a predetermined number have been cut. Then the angle of the saw blade must be adjusted to make the seat cut. A careful study of the various cuts that must be made for each member of the truss will show that all members except the lower chord splice require two separate saw setups to make the necessary cuts at the angles required. It is obvious that one saw is not adequate, and a better method must be found.

Flow diagram using two saws. Placing two power saws in the flow diagram (figure 4-4, on page 4-10) is a more workable solution. In comparing figures 4-2 and 4-4, notice that the operations, storages and delays, and transportations have each been reduced in number. Also notice that neither of these flow diagrams indicates how far the movements are, how long it takes for each step, or how many workers are required to perform the various steps. This information is given on the flow process chart.

FIGURE 4-2
FLOW DIAGRAM, USING ONE SAW

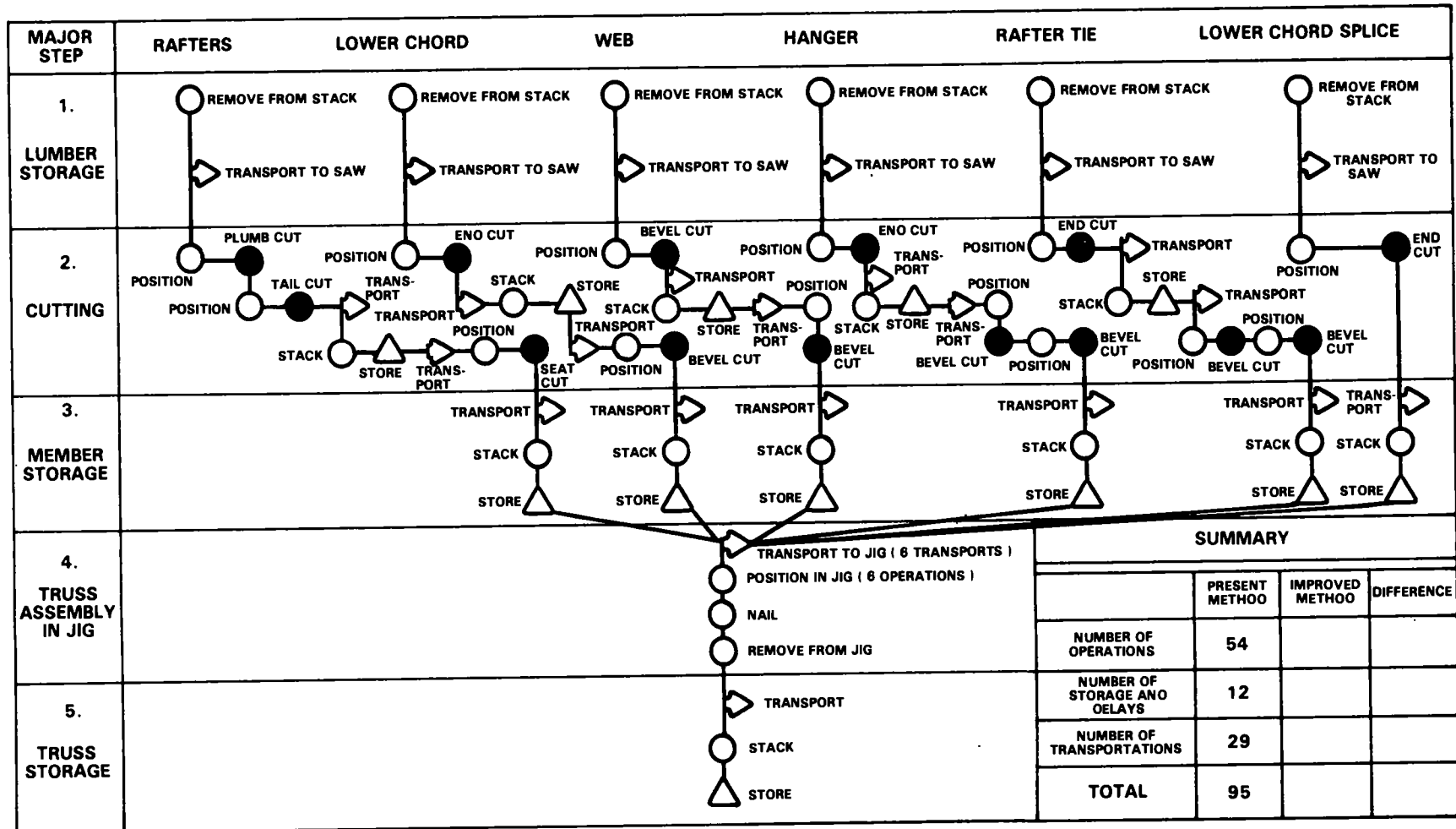
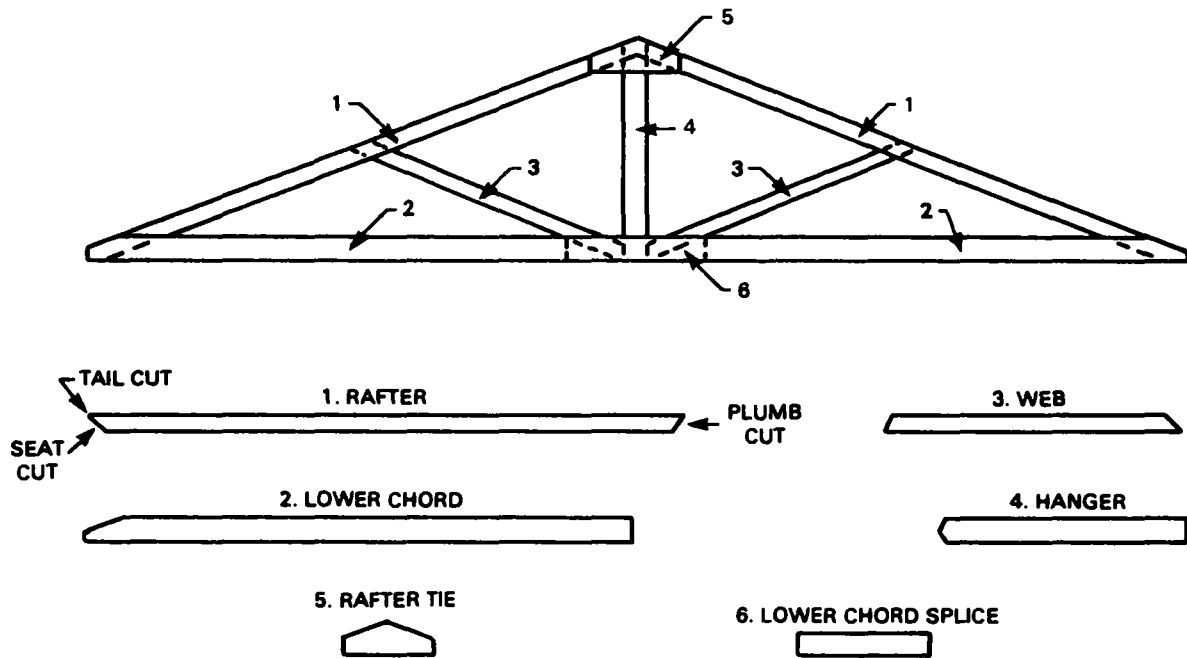
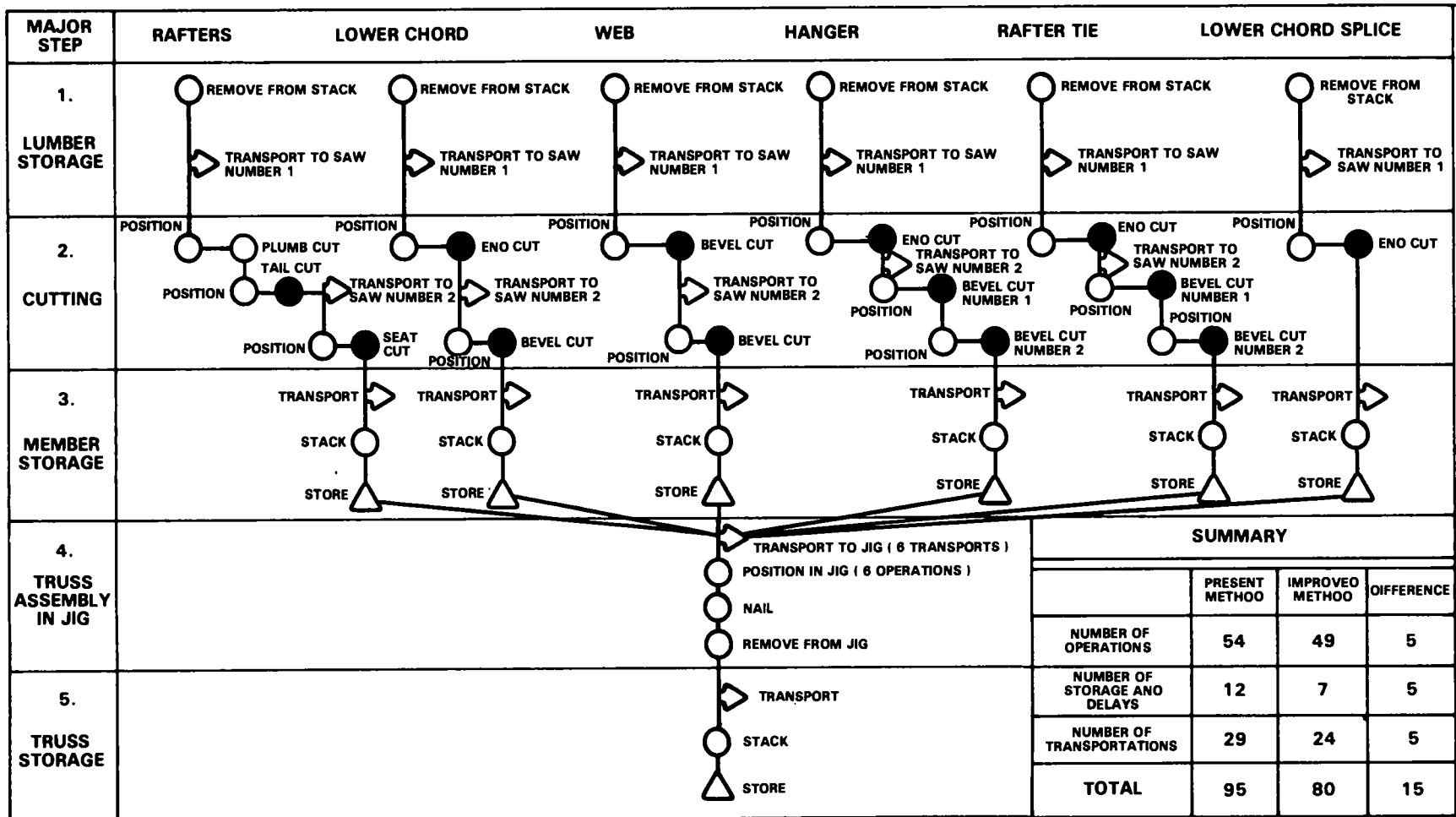


FIGURE 4-3
ROOF TRUSS



Item no.	Member	Pieces truss	Length in place	Size	Common length	Pieces length	Saw setups
1	Rafter	2	10'-11"	2" x 4"	12'	1	2
2	Lower chord	2	10'- 0"	1" x 6"	10'	1	2
3	Web	2	5'- 5"	2" x 4"	12'	2	2
4	Hanger	1	4'- 4½"	2" x 6"	14'	3	2
5	Rafter tie	1	1'- 6"	1" x 8"	12'	8	2
6	Lower chord splice	1	2'- 6"	2" x 6"	10'	4	1

FIGURE 4-4
FLOW DIAGRAM, USING TWO SAWS



FLOW PROCESS CHART—THE SECOND STEP

Use the flow process chart to analyze the details of the operation. As the second step, the chart is a tabulation of the chronological sequence of the details of each process in the flow diagram (first step, page 4-6). In addition, the flow process chart includes the time needed to accomplish each detail and the distances that materials are transported.

Preparation. A Flow Process Chart, DD Form 1723, provides a standard for process charting. The process of cutting rafters (figure 4-5, page 4-13), using two saws and based on the flow diagram (figure 4-4), will serve as an example.

Note. If DD Form 1723 is not available, use a blank sheet and follow the format shown in figure 4-5.

Complete the data in the upper left corner on the form, being specific in regard to the identification of the process to be charted, the person or material being traced through the process, and the places or times that the process begins and ends.

List each detail of the process in brief narrative form in the left column (details of method) on the chart. This listing is developed from the flow, and details should be plotted in the sequence plotted therein.

In the column of symbols, trace the process by connecting, with a penciled line, the symbols which are appropriate to each step.

Enter in the distance column, where appropriate, how far the item will be moved.

In the quantity column, show the number of items being processed during each particular detail.

Opposite each detail in the time column, enter how long each step should take; the time factor should be stated under the column headed Notes.

Enter the total number of actions included by each type of activity in the Summary box in the upper right corner of the form.

Note. Use the flow process chart to detail either the movement of materials or the movement of workers through a process system. Do not detail the movements of both on the same form because it will confuse the user.

Analysis. Other columns are for analysis when reviewing the process. Study each step in detail. Is it possible to eliminate or combine certain details? Can distances and times be further reduced? Should sequences be changed? Can some operations be simplified? Who does the work? Who could do it better? Can changes be made to permit a person with less training and skill or more efficient machines to do the work? Where is the

work done? Could it be done somewhere else more economically? When is the work to be done? Would it be better to do it at some other time? How is the work to be done? This suggests alternate possible machine methods or the use of machines instead of hand labor.

Inefficient methods. Such an analysis will show any unnecessary handling, excessive movements of materials, duplication of effort, excessive number of steps taken, number and kind of delays, labor inefficiencies, and so on. These are only part of the possible questions to ask about each recorded step in the operation in order to try to reduce the steps to a minimum and arrive at the simplest "paper picture" of the method. The more questions asked, the more a questioning and critical attitude toward work methods is developed.

Solutions. As the manager develops the best method of processing each member of the truss, site layout requirements may be analyzed in greater detail. Location of material stacks, equipment, parts storage, and assembly areas must be plotted and distances computed at the same time as the manager develops the process charts.

Control Factor. The end result of process charting is the calculation of the production rate for the given process. In general, the steps which cannot be accomplished concurrently control the time it takes to perform a process. In other words, they establish the control factor.

Establishment. To determine the control factor, first list all operations and the time required for each. Second, determine those which are performed concurrently. The remaining operations (those which cannot be accomplished concurrently) establish the control factor.

Example. In figure 4-5 there are eight operations (details 1, 3 through 6, 8, 9, and 11) requiring a total of 18 seconds. Four operations (details 1, 8, 9, and 11) can be accomplished concurrently. Hence, details 3 through 6 are the only operations which cannot be accomplished concurrently. Then, the analyst circles the time required for these operations on the flow process chart and establishes the control factor as eight seconds per unit. This data is entered in the column under notes, and the production rate is calculated as shown. In addition to figure 4-5, figures 4-6 through 4-10, on pages 4-14 through 4-18, show the plotting of the control factor and the resulting calculations of the production rate for each member of the truss (figure 4-3).

Note. In some flow process charts, more than one series of operations may be taken as the control factor. For example, in figure 4-6, steps 3 and 4 could be used as the control factor instead of steps 6 and 7 (encircled). None of the steps selected as the control factor can be those taking place concurrently, regardless of the sequence selected.

FIGURE 4-5
FLOW PROCESS CHART, CUTTING RAFTERS

FLOW PROCESS CHART										NUMBER J.O.0000	PAGE NO. 1	NO. OF PAGES 1																			
PROCESS Cutting Rafters										SUMMARY																					
☐ MAN OR ☒ MATERIAL										ACTIONS																					
										PRESENT		PROPOSED		DIFFERENCE																	
										NO.	TIME	NO.	TIME	NO.	TIME																
CHART BEGINS At Lumber Storage										CHART ENDS At Parts Storage																					
CHARTED BY CPT Behring										DATE 2 July																					
ORGANIZATION 477th Engr Const Bn										DISTANCE TRAVELLED (Feet) 56 ft																					
DETAILS OF ☐ PRESENT ☐ PROPOSED METHOD										OPERATION		TRANSPORTATION		INSPECTION		DELAY		STORAGE		DISTANCE IN FEET		QUANTITY		TIME		ANALYSIS WHY?		NOTES		ANALYSIS	
										WHAT?		WHERE?		WHO?		HOW?															
1 Remove lumber from storage										○		◇		□		▽				1		3									
2 Transport to saw table										○		◇		□		▽				18		1		5							
3 Position for plumb cut										○		◇		□		▽				1		2									
4 Make plumb cut										●		◇		□		▽				1		2									
5 Position for tail cut										○		◇		□		▽				1		2									
6 Make tail cut										●		◇		□		▽				1		2									
7 Trans to 2d saw										○		◇		□		▽				14		1		4				With 2 saws			
8 Position for seat cut										○		◇		□		▽				1		2						Control factor is			
9 Make seat cut										●		◇		□		▽				1		2						reduced from			
10 On conveyor belt to storage										○		◇		□		▽				24		1		6				12 sec to 8 sec			
11 Remove fr convey stack										○		◇		□		▽				1		3						because operations			
12 Rafter in storage.										○		◇		□		▽												run concurrently.			
13										○		◇		□		▽															
14										○		◇		□		▽										Production Rate =					
15										○		◇		□		▽										1 rafter each					
16										○		◇		□		▽										8 sec or					
17										○		◇		□		▽										16 sec/truss unit.					
18										○		◇		□		▽										Assume 70% eff					
19										○		◇		□		▽										work hour 50 min					
20										○		◇		□		▽										$\frac{60 \times 50 \times .70}{16} = \frac{2100}{16} =$					
21										○		◇		□		▽										131 Truss units/hr					

FIGURE 4-6
FLOW PROCESS CHART, CUTTING LOWER CHORDS

FLOW PROCESS CHART										NUMBER J.O.000	PAGE NO. 1	NO. OF PAGES 1							
PROCESS Cutting Lower Chords										SUMMARY									
☐ MAN OR ☒ MATERIAL										ACTIONS		PRESENT	PROPOSED	DIFFERENCE					
										NO.	TIME	NO.	TIME	NO.	TIME				
										☐ OPERATIONS			6	14					
										☐ TRANSPORTATIONS			3	16					
										☐ INSPECTIONS			0	0					
										☐ DELAYS			0	0					
										☐ STORAGES			1	--					
CHART BEGINS Lumber Storage CHART ENDS Parts Storage CHARTED BY CPT Behring DATE 2 July ORGANIZATION 477th Engr Const Bn										DISTANCE TRAVELLED (Feet)		62 ft							
DETAILS OF	PRESENT	METHOD	OPERATION	TRANSPORTATION	INSPECTION	DELAY	STORAGE	DISTANCE IN FEET	QUANTITY	TIME	ANALYSIS WHY?	NOTES	ANALYSIS	ELIMINATE	COMBINE	SEQUENCE	CHANGE	PERSON	IMPROVE
1 Remove from lumber storage			☐	☐	☐	☐	☐		1	3									
2 Trans to saw table			☐	☐	☐	☐	☐	18	1	5									
3 Position for 1st cut			☐	☐	☐	☐	☐		1	2									
4 Make 1st cut			☒	☐	☐	☐	☐		1	2									
5 Trans to 2d saw			☐	☐	☐	☐	☐	14	1	4									
6 Position for 2d cut			☐	☐	☐	☐	☐		1	2									
7 Make 2d cut			☒	☐	☐	☐	☐		1	2		With 2 saws							
8 On conveyor to parts storage			☐	☐	☐	☐	☐	30	1	7		Control factor =							
9 Remove fr convey, stack			☐	☐	☐	☐	☐		1	3		4 seconds per							
10 Chord in storage			☐	☐	☐	☐	☐					Chord or 8 sec/							
11			☐	☐	☐	☐	☐					Truss unit							
12			☐	☐	☐	☐	☐					Eff. 70%							
13			☐	☐	☐	☐	☐					Working hour 50 min							
14			☐	☐	☐	☐	☐					$\frac{60 \times 50 \times .70}{8} =$							
15			☐	☐	☐	☐	☐					262 truss units							
16			☐	☐	☐	☐	☐					per hour							
17			☐	☐	☐	☐	☐												
18			☐	☐	☐	☐	☐												
19			☐	☐	☐	☐	☐												
20			☐	☐	☐	☐	☐												
21			☐	☐	☐	☐	☐												

FIGURE 4-7
FLOW PROCESS CHART, CUTTING WEBS

FLOW PROCESS CHART										NUMBER J.O.XXXX		PAGE NO. 1		NO. OF PAGES 1					
PROCESS Cutting Webs										SUMMARY									
☐ MAN OR ☒ MATERIAL CHART BEGINS At Lumber Stack CHART ENDS Parts Storage CHARTED BY CPT Behring DATE 2 July ORGANIZATION 477th Engr Const Bn										ACTIONS		PRESENT		PROPOSED		DIFFERENCE			
										NO.	TIME	NO.	TIME	NO.	TIME				
										☐ OPERATIONS			6	15					
										☐ TRANSPORTATIONS			3	18					
										☐ INSPECTIONS			0	0					
										☐ DELAYS			0	0					
										☐ STORAGES			1						
										DISTANCE TRAVELLED (Feet)		68 ft							
DETAILS OF	PRESENT	METHOD	OPERATION	TRANSPORTATION	INSPECTION	DELAY	STORAGE	DISTANCE IN FEET	QUANTITY	TIME	ANALYSIS WHY?	NOTES	ANALYSIS	ELIMINATE	COMBINE	SEQUENCE	CHANGE	PERSON	IMPROVE
1									1	3		Time in seconds.							
2								27	1	7		Two webs can be cut							
3									1	2		from one piece. In							
4									1	2		the first four							
5									1	2		steps until the first							
6								14	2	4		cut is made treat as							
7								2	3			single piece. After							
8								9	2	7		1st cut, handle the							
9								45	2	3		two half sections to-							
10									2	3		gether and make 2d							
11												cut on these at							
12												same time.							
13												Eff. 70% wk hr 50 min							
14												Control factor 5 sec							
15												$.60 \times 50 \times .70 = 420$							
16												truss units per hr.							
17																			
18																			
19																			
20																			
21																			

FIGURE 4-8
FLOW PROCESS CHART, CUTTING HANGERS

FLOW PROCESS CHART										NUMBER J.O.000		PAGE NO. 1		NO. OF PAGES 1																																																																	
PROCESS Cutting Hangers ☐ MAN OR ☒ MATERIAL										SUMMARY <table border="1"> <tr> <th colspan="2">ACTIONS</th> <th colspan="2">PRESENT</th> <th colspan="2">PROPOSED</th> <th colspan="2">DIFFERENCE</th> </tr> <tr> <th></th> <th></th> <th>NO</th> <th>TIME</th> <th>NO</th> <th>TIME</th> <th>NO</th> <th>TIME</th> </tr> <tr> <td>☐ OPERATIONS</td> <td></td> <td></td> <td></td> <td>10</td> <td>31</td> <td></td> <td></td> </tr> <tr> <td>☐ TRANSPORTATIONS</td> <td></td> <td></td> <td></td> <td>3</td> <td>16</td> <td></td> <td></td> </tr> <tr> <td>☐ INSPECTIONS</td> <td></td> <td></td> <td></td> <td>0</td> <td>0</td> <td></td> <td></td> </tr> <tr> <td>☐ DELAYS</td> <td></td> <td></td> <td></td> <td>1</td> <td>0</td> <td></td> <td></td> </tr> <tr> <td>☐ STORAGES</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="4">DISTANCE TRAVELLED (Feet)</td> <td colspan="2">59 ft</td> <td colspan="2"></td> </tr> </table>						ACTIONS		PRESENT		PROPOSED		DIFFERENCE				NO	TIME	NO	TIME	NO	TIME	☐ OPERATIONS				10	31			☐ TRANSPORTATIONS				3	16			☐ INSPECTIONS				0	0			☐ DELAYS				1	0			☐ STORAGES								DISTANCE TRAVELLED (Feet)				59 ft			
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1 Remove length fr storage		○	→	□	▽			3							Like the web, one																																																																
2 Trans to saw table		○	→	□	▽		15	1	5						length is sufficient																																																																
3 Position for 1st st cut		○	→	□	▽		1	3							for 3 pcs. The 1st																																																																
4 Make first cut		●	→	□	▽		1	2							& 2d cut made on the																																																																
5 Position for 2d st cut		○	→	□	▽		1	3							first saw gives three																																																																
6 Make 2d cut		●	→	□	▽		1	2							pcs. The three																																																																
7 Trans 3 pcs to 2d saw		○	→	□	▽		14	3	4						pcs are then placed																																																																
8 Position stack of 3 pcs for 1st cut		○	→	□	▽		3	4							together on the																																																																
9 Make first cut		●	→	□	▽		3	3							second saw. The first																																																																
10 Turn 3 pcs over and position for 2d cut		○	→	□	▽		3	5							cut is made on the																																																																
11 Make 2d cut		●	→	□	▽		3	3							stack, stack is																																																																
12 3 Pcs on conveyor to storage*		○	→	□	▽		24 36	3	7						turned and second																																																																
13 Remove fr conveyor & stack		○	→	□	▽		3	3							cut made. This opn																																																																
14 Hangers in storage		○	→	□	▽										results in 3 hangers.																																																																
15		○	→	□	▽										Control factor = $\frac{15}{3}$																																																																
16 *Distances to storage		○	→	□	▽										or sec/truss unit.																																																																
17 for hangers are 24 ft		○	→	□	▽										Eff. 70% wk hr 50 min																																																																
18 and 36 ft. Average		○	→	□	▽										production rate																																																																
19 would be 30 ft.		○	→	□	▽										$\frac{60 \times 50 \times .70}{5} = 420$																																																																
20		○	→	□	▽										Truss units/hr.																																																																
21		○	→	□	▽																																																																										

FIGURE 4-9
FLOW PROCESS CHART, CUTTING RAFTER TIES

FLOW PROCESS CHART										NUMBER J.O.0000		PAGE NO. 1		NO. OF PAGES 1																																																																	
PROCESS Cutting Rafter Ties ☐ MAN OR ☒ MATERIAL										SUMMARY <table border="1"> <tr> <th colspan="2">ACTIONS</th> <th colspan="2">PRESENT</th> <th colspan="2">PROPOSED</th> <th colspan="2">DIFFERENCE</th> </tr> <tr> <th>NO.</th> <th>TIME</th> <th>NO.</th> <th>TIME</th> <th>NO.</th> <th>TIME</th> <th>NO.</th> <th>TIME</th> </tr> <tr> <td>○ OPERATIONS</td> <td></td> <td></td> <td></td> <td>15</td> <td>77</td> <td></td> <td></td> </tr> <tr> <td>◇ TRANSPORTATIONS</td> <td></td> <td></td> <td></td> <td>5</td> <td>21</td> <td></td> <td></td> </tr> <tr> <td>□ INSPECTIONS</td> <td></td> <td></td> <td></td> <td>0</td> <td>-</td> <td></td> <td></td> </tr> <tr> <td>△ DELAYS</td> <td></td> <td></td> <td></td> <td>0</td> <td>10</td> <td></td> <td></td> </tr> <tr> <td>▽ STORAGES</td> <td></td> <td></td> <td></td> <td>1</td> <td>-</td> <td></td> <td></td> </tr> <tr> <td colspan="4">DISTANCE TRAVELLED (Feet)</td> <td colspan="4">53 ft</td> </tr> </table>						ACTIONS		PRESENT		PROPOSED		DIFFERENCE		NO.	TIME	NO.	TIME	NO.	TIME	NO.	TIME	○ OPERATIONS				15	77			◇ TRANSPORTATIONS				5	21			□ INSPECTIONS				0	-			△ DELAYS				0	10			▽ STORAGES				1	-			DISTANCE TRAVELLED (Feet)				53 ft			
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									WHAT?	WHERE?	WHEN?	HOW?		ELIMINATE	COMBINE	SEQUENCE	CHANGE PLACE	PERSON	IMPROVE																																																												
1 Remove stock from lumber storage		○	◇	□	△	▽		1	3																																																																						
2 Transport to 1st saw		○	◇	□	△	▽	12	1	4																																																																						
3 Position 6 times & make 6 cuts		●	◇	□	△	▽		1	30																																																																						
4 Trans 7 pcs to & stack at 2d saw		○	◇	□	△	▽	14	7	10																																																																						
5 Remove 2 pcs from stack and position for 1st cut		○	◇	□	△	▽		2	4																																																																						
6 Make 1st cut		●	◇	□	△	▽		2	3																																																																						
7 Turn 2 pcs over and position for 2d cut		○	◇	□	△	▽		2	4																																																																						
8 Make 2d cut		●	◇	□	△	▽		2	3																																																																						
9 Position two more pcs for 1st cut		○	◇	□	△	▽		2	4																																																																						
10 Make 1st cut		●	◇	□	△	▽		2	3																																																																						
11 Turn 2 pcs over and position for 2d cut		○	◇	□	△	▽		2	4																																																																						
12 Make 2d cut		●	◇	□	△	▽		2	3																																																																						
13 Position two more pcs for 1st cut		○	◇	□	△	▽		2	4																																																																						
14 Make 1st cut		●	◇	□	△	▽		2	3																																																																						
15 Turn over and position for 2d cut		○	◇	□	△	▽		2	4																																																																						
16 Make 2d cut		●	◇	□	△	▽		2	3																																																																						
17 Last 2 pcs on conveyor* to storage		○	◇	□	△	▽	15 39	2	7																																																																						
18 Remove fr conveyor stack		○	◇	□	△	▽		2																																																																							
19 Collar ties in storage		○	◇	□	△	▽																																																																									
20 *Distances to storage for rafter ties 15 ft and 39 ft		○	◇	□	△	▽																																																																									
21 Average 27 ft		○	◇	□	△	▽																																																																									

PROPORTIONING

In the flow process charts (figures 4-5 through 4-10), except for webs and hangers, the cutting rate (based on a 50-minute hour) varies for each member unit. To achieve balanced production of the several parts making up the final product (the truss), analyze the production rate of each part and establish the proportionate cutting time which, when allotted to each member, will result in a balanced production.

Production Rate Analysis. Table 4-2 shows such an analysis for balanced production of the member units required for 4,000 trusses. Since the cutting rates are based on the flow process charts for each member unit, the numbers in the cutting rate column (column C) remain constant. Likewise, the cutting ratios (column E) will remain constant for each member, no matter how many truss units are to be built.

TABLE 4-2
PRODUCTION ANALYSIS

(Cutting times from flow process charts, figures 4-5 through 4-10)

(A) Member	(B) Required number of truss units	(C) ¹ Cutting rate per 50 minute period	(D) Total number of 50 minute periods required (B÷C)	(E) ² Cutting period ratio	(F) Number of 50 minute periods allotted for the 10 hour workday (10xE)	(G) Balanced production total truss units cut in 10 hour workday (FxC)
Rafter	4,000 ³	131	30.5	.352	3.52	461
Lower chord	4,000 ³	262	15.3	.176	1.76	461
Web	4,000 ³	420	9.5	.11	1.1	461
Hanger	4,000	420	9.5	.11	1.1	461
Rafter tie	4,000	300	13.3	.153	1.53	461
Lower chord splice	4,000	467	8.6	.099	.99	461
Total			86.7	1.	10.	

¹Quantities are derived from rates computed in figures 4-5 through 4-10. All of these simple process charts reflect the actual production time required to cut each member unit; that is, production time equals 50 minutes/hour.

$$\text{Production hour} = \frac{\text{man-hours}}{6} \times 5$$

$$\text{Man-hours} = \frac{\text{number of 50 minute periods}}{5} \times 6$$

$$\text{Cutting period ratio} = \frac{\text{member cutting time (column D)}}{\text{total periods (column D)}}$$

The above ratio is used to determine the relative cutting periods of one member to another in order to maintain

balanced production. Summary of cutting operations:

$$\text{Unit cutting rate} = \frac{4,000}{86.7} \times 46.1$$

$$\text{Number of truss units/clay} = 10 \times 46.1 = 461$$

$$\text{Number of days required} = \frac{86.7}{10} \times 8.67$$

Check: 8.67 days x 461 truss units/day = 4,000 truss units, total.

$$\text{Number of man-hours for 9-member crew} = 9 \times 10 \times 8.67 = 780.$$

³These numbers represent pairs of members.

Balanced Production. Balanced production for any period of time can be determined from table 4-2 as follows:

Example 1. How many rafter units should be produced to balance production for truss units in six 50-minute hours?

Step 1. Determine number of production hours to be allotted for cutting rafters. Cutting period ratio (column E, table 4-2) is 0.352. Therefore,

$$0.352 \times 6 = 2.112.$$

Step 2. Determine number of rafters to be cut: Cutting rate per 50-minute period (column C, table 4-2) = 131.

$$131 \times 2.112 = 277 \text{ rafter units.}$$

Check—

$$6 \times 46.1 = 277 \text{ truss units}$$

$$0.6 \times 461 = 277 \text{ truss units}$$

Example 2. With a crew of nine workers, how many man-hours are required for cutting the 277 rafter units computed in example 1? Man-hours = Cutting period ratio.

$$\left\{ \frac{\text{Number of 50-minute periods}}{5} \times 6 \right\} \text{ Crew Size} = 0.352 \left\{ \frac{6}{5} \times 6 \right\} 9 = 22.8$$

(for cutting 277 rafters)

SITE LAYOUT—THE THIRD STEP

Once the components of the plant have been at least tentatively selected, prepare a layout to show the location of the various construction aids.

Principles. While each job has its own characteristic problems and plant requirements, principles which apply to all jobs include the following:

- The layout of the site should be balanced. Select equipment which can be used at its maximum capacity at all times.
- Place stockpiles of materials as close as possible to the place of final use. Where storage space is limited, place the heaviest or most unwieldy materials closest to the point of use to reduce handling.
- Design the material delivery schedule to eliminate as much on-the-job storage as possible. On-the-job storage diverts considerable effort from the main job, increases the job area, and necessitates rehandling.

- Locate general utility equipment, such as cranes and air compressors, to serve as large an area as possible to keep movement of such equipment to a minimum.
- Locate mixers, batchers, power saws, crushing and screening plants, and similar facilities to keep materials handling to a minimum.
- Maintain supplies of petroleum, oil and lubricants, water, handtools, and equipment repair parts at realistic levels.
- Avoid traffic tieups by using one-way roads or turnarounds.
- Arrange material flow so that it may be helped by gravity, where possible.
- Provide medical facilities. They may range from single first-aid kits on a small job to a complete aid station with trained aid personnel available at all times on a large project.
- Provide safety measures for the prevention of injuries when planning the layout. These may include dust alleviation and such items as protective equipment and lighting for night work.
- Provide fire prevention and protection, particularly during dry and/or cold weather.

Preparation. In the development of an efficient system for processing materials through the plant, it is very unlikely that the first layout will meet all requirements. Several layouts may be prepared at this stage, only to be discarded as new complications become apparent. The use of graph paper will permit rapid freehand sketching roughly to scale so that time spent in this effort will be held to a minimum. Time conscientiously expended in layout preparation will prevent the loss of valuable man-hours later at the job site.

Trial layouts. When making a site layout, plan the whole and then work at the details. When planning the processes, keep in mind the available equipment. Once the processes are established, make trial site layouts on scaled paper to determine how to do the processes most efficiently. Many typical layouts may be found in references dealing with particular operations such as rock crushing and central mixing. These serve as excellent starting points for a detailed analysis of a specific project. Sample layouts of this type are shown in appendix D.

First layout. Layout sketch number 1 in figure 4-11, on page 4-22, the first attempt in this particular problem, does have possibilities. However, it is apparent that either all cutting operations must be completed before starting assembly of trusses, or the trailer-mounted saws will have to be

moved frequently in order to maintain a balance of cut parts available for assembly.

Second layout. A second layout, given in figure 4-12, is more feasible. The location of materials and the distances coincide with cutting operations as outlined in the process charts (figures 4-5 through 4-10). Up to this point, the layout seems satisfactory. However, in developing a process of assembling the trusses to be approximately equal to the cutting rate, you will see that parts storage and assembly facilities are not realistic.

Third layout. Layout number 3 (figure 4-13) now appears to be a workable layout because it reflects the flow process charts (figures 4-5 through 4-10). From the planner's viewpoint, there is both a layout and a processing system which will produce roof trusses in accordance with the estimate. Of equal importance is the fact that no time will be lost in setting up the fabrication yard. Supervisory personnel in the field will know exactly what is intended. Every detail developed by the planner is on paper in legible form for them to execute.

FIGURE 4-11
LAYOUT SKETCH NUMBER 1 (TRIAL METHOD)

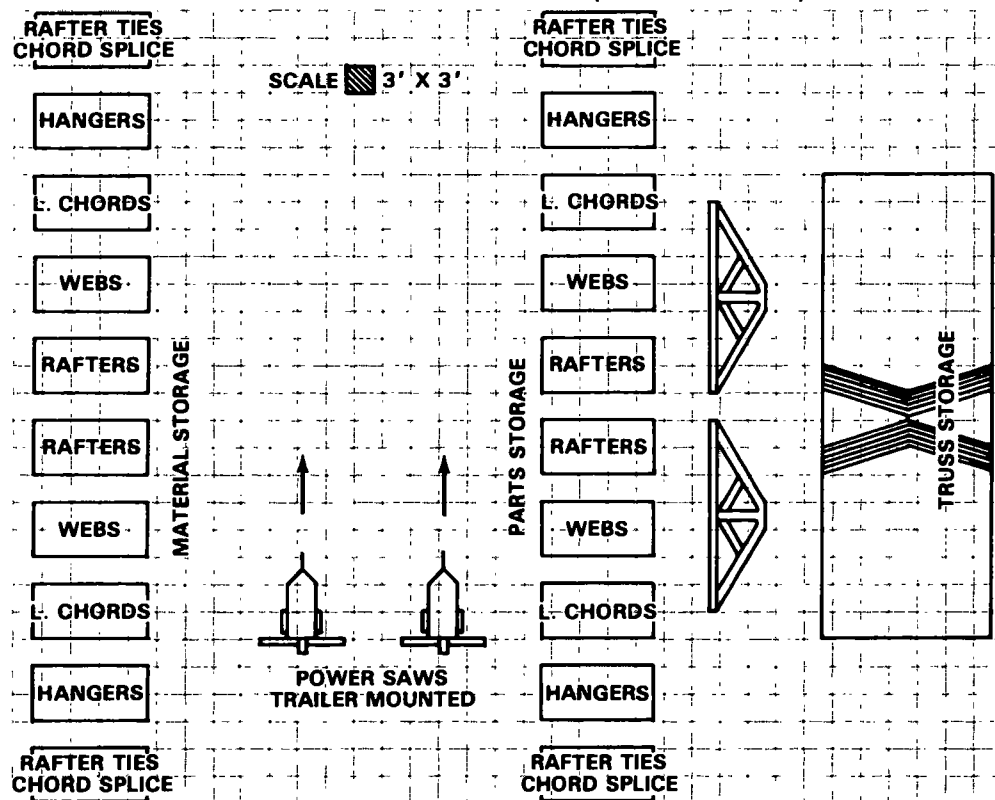


FIGURE 4-12
LAYOUT SKETCH NUMBER 2 (TRIAL METHOD)

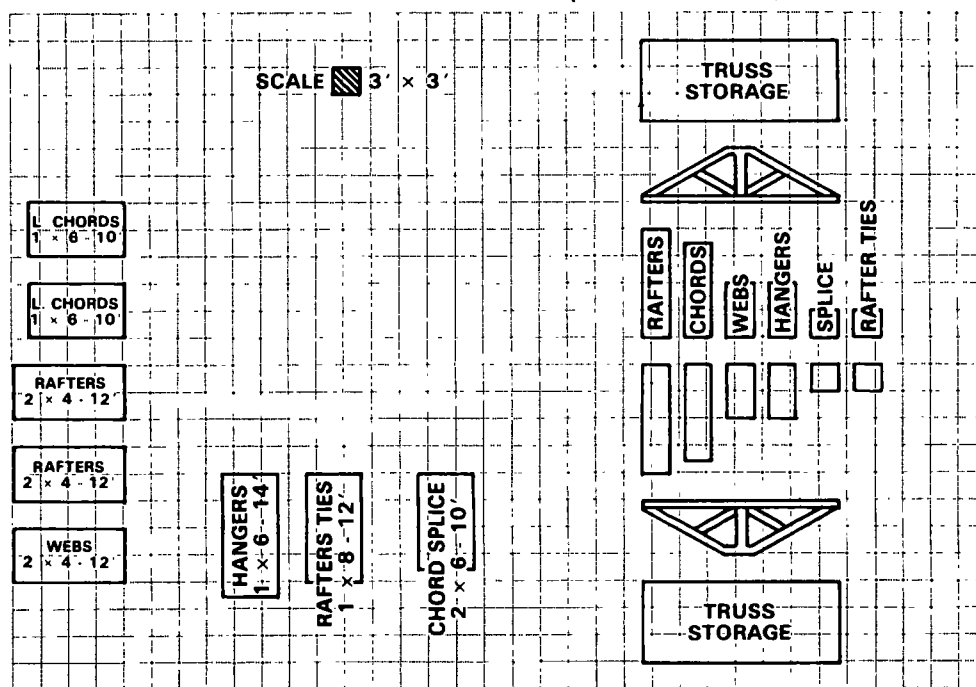
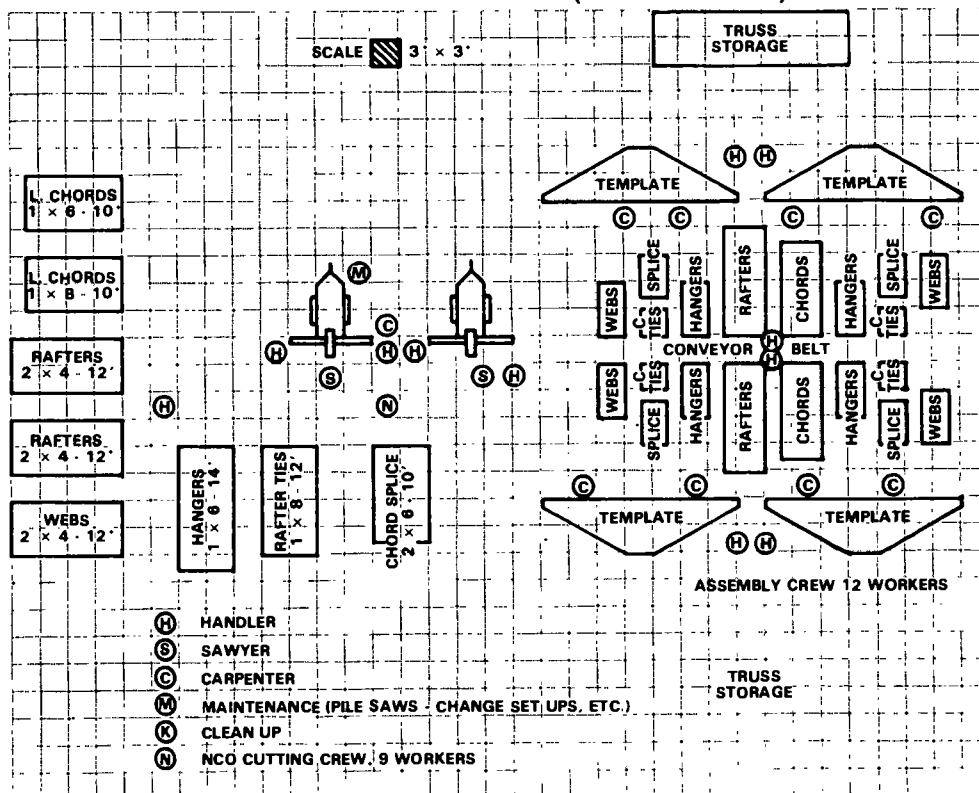


FIGURE 4-13
LAYOUT SKETCH NUMBER 3 (TRIAL METHOD)



Assembly Phase. An analysis similar to the one presented here may be carried out for the assembly phase of the truss fabrication. One analysis using a crew of 12 yields a unit assembly rate of 46.64. This means that $4,000/46.64 = 85.8$ hours (or 8.58 days) will be required for assembly with the specified 12-worker crew. This yields a total of 1,030 man-hours.

CONCLUSION

If this method of analyzing site layout requirements appears to be too detailed and time-consuming, consider the usual method and then compare the merits of each.

Usual Method. In the detailed planning stage, the estimators develop figures, which show the rates of production that should be accomplished, as well as the overall time required to perform each item of work. However, even though such an estimate contains the backup calculations that result in the final figures, rarely can anyone other than the estimator who compiled it determine the factors upon which the figures are based. Needless to say, when the site is to be laid out and the production process set up, no plan exists. The individual charged with supervision is expected to set up the site and accomplish the task with the rates of production derived by the estimator. However, without knowing the determining factors for the figures, the supervisor can rely only on technical knowledge and experience. The inevitable result is confusion when the job is getting under way, and a double-shift operation in the latter stages in an effort to meet deadlines.

Flow Process Chart Method. Use of the flow process chart establishes a definite sequence of operations that reduces the overall process to a minimum number of operations, movements, and delays. On the flow process chart we determine WHAT takes place.

Established criteria. The flow process charts provide a means of analyzing each operation and movement of materials to determine how, where, and when each operation is performed. Criteria are established for simultaneous development of the layout plan.

Visible data. All data are visible, easily interpreted, and available for viewing by others to see whether, based on experience, further improvements can be developed before placing the plan into operation. When ready to execute, orders can be issued with confidence for the supervisor knows that operations will be set up exactly as visualized by the estimator.

Future reference. Furthermore, these data provide a basis for developing and recording further improvements once the job is under way. After the job is completed, there are factual recorded data to be filed for reference in planning future jobs of similar nature.

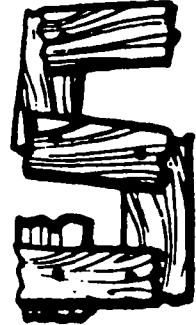
Problem. In this chapter the location of the fabrication yard is considered to have been fixed. There is the requirement for 4,000 20-foot trusses for

standard TO buildings (figure 4-3). The problem is to determine the following:

- Layout of fabrication yard.
- Size of labor crew required.
- Distribution of labor to ensure efficient production.
- Man-hours required to produce each truss unit.
- Total production time required.

Solution.

- The layout of the fabrication yard is given in the layout sketch shown in figure 4-13. The Assembly Phase paragraph explains that it is a workable layout because it includes all operations outlined in the flow process charts (figures 4-5 through 4-10).
- The layout sketch also shows the size of the labor crew required: one cutting crew of nine workers, four assembly crews of three workers each.
- Layout sketch number 3 (figure 4-13) shows a distribution of labor for effective cutting and assembling.
- Man-hours required to produce each truss are 0.195 for cutting and 0.258 for assembly.
- The total time required is 9.08 days.



Chapter

Controlling Functions

SUPERVISION

STEPS

Supervision is the direction and control of subordinates; that is, telling people what to do, then making sure they do it. There are three steps in the supervision process.

Set Objective Standards. The key word in this step is “objective.” The standard which is set must mean the same to both subordinates and supervisor. In construction, standards of percentage completion are often vague. For example, if a unit was directed to have the construction of six concrete slabs 50 percent complete by a certain date, should it have three slabs complete or forms set for all six? This problem can be avoided by directing the unit to complete specific activities in a detailed CPM network.

Measure Performance. Performance can be measured either by inspection or by report. These control devices will be further discussed.

Make Adjustments. If performance does not meet standards, adjustments can be made in two ways: either improve performance or lower standards. Most of the time improving performance is appropriate. At times, however, the supervisor may face a situation where the standard becomes unrealistic; for example, a schedule is based on poor estimates or fails to reflect delays. In these cases, the supervisor must be able to adjust the schedule or be given additional resources.

COMMUNICATIONS

The essence of good supervision is good communications. Objective standards cannot be set when orders are not communicated clearly. Performance cannot be measured when the communications system does not allow for timely reports. Adjustments cannot be made unless there is provision in communications for feedback. Communications may be oral or written. Each method has inherent advantages and disadvantages.

Written Communications. Written communications for supervision include communications devices designed for a downward flow of orders from supervisor to subordinate, such as regulations, SOPs, directives, and policy memoranda, and a communications device for upward flow of information from subordinate to supervisor, reports. The downward communications devices used for supervision do not have as their purpose the dissemination of information. Regulations, SOPs, directives, and policy memoranda are designed to tell people what to do, not to inform. Any information contained in these directive communications should be necessary for the clarification of the order. Information of a general nature can be transmitted through other communications devices, such as manuals, circulars, or bulletins. Thus, regulations, SOPs, directives, and policy memoranda should be written to accomplish the first step in the supervision process, the setting of objective standards. Similarly, the upward-flow communications device, the supervisory report, has as its function the accomplishment of the second supervision step, measuring performance against standards. The supervisory report, then, must correspond with an order. Performance cannot be measured against a standard which has not been set; nor should a standard be set if there is no mechanism to verify enforcement.

Advantages. Written communications provide a record of both standards and performance. This record is useful for both continuity and later reference.

- **High level of accuracy, uniformity, and completeness.** Written directives can be prepared meticulously so that all details are spelled out. Even if extreme care is taken in the preparation of a briefing, the subordinate does not have the briefing to refer to as he does a written directive. Plans and specifications are examples of standards which must be transmitted to paper to ensure accuracy. Reports which must be consolidated at higher headquarters are often written to ensure uniformity.
- **Time savings.** When a directive applies to many subordinates, often time can be saved by sending a written directive rather than by attempting to reach each subordinate individually or in special meetings.

Disadvantages. When a regulation, SOP, directive, or policy memorandum is sent down through several levels of command, there is a time lag in implementation, a time lag in measurement of performance, and a further

time lag in adjustments of the standard of performance. This may result in inappropriate standards being established and maintained by higher headquarters.

- **Large administrative effort.** Written communications must be drafted, reviewed, printed, distributed, and filed. All of this requires a great deal of clerical support.
- **Inflexibility.** It is difficult to change a regulation, SOP, directive, or policy memorandum in the face of changing circumstances. This is particularly true if the order has come from several command levels above the working unit.

Oral Communications. Oral communications include inspections, conferences, and briefings. These are two-way communications devices because with face-to-face contact there is always the opportunity to exchange information. Just as with written communications, oral communications for supervision should accomplish the three supervision steps.

Immediate feedback. The third step in the supervision process is to make adjustments when performance does not meet standards. This step is greatly simplified by oral communication. Often, through questions or discussion, either the performance or the standards can be adjusted immediately.

Little administrative effort. Oral transmission of information on standards and performance saves clerical effort. A supervisor may stress oral communications in cases where administrative support is not available.

Flexibility. In an inspection, conference, or briefing, the face-to-face contact between supervisor and subordinate makes possible a quick response to changing circumstances. Further, with oral communications, no long process is needed to change a previous decision.

Written Versus Oral Communications. Generally, written communications are over-used. Too many regulations are written with limited applicability. SOPs are written for procedures which should be left to the discretion of subordinates. Reports may be submitted long after their usefulness has ended. At each level of command, written supervisory communications should be examined at least every six months to determine which regulations, SOPs, directives, policy memoranda, and reports are obsolete and which would be better suited for oral communications.

INSPECTIONS AND REPORTS

INSPECTIONS

The inspection is a control device which gives the commander first-hand knowledge of a situation and provides immediate feedback. An Army

proverb states that "a unit does well what the commander inspects." The most effective way of ensuring that vital functions are not neglected is through a system of inspections. Because they are time-consuming, and time is the supervisor's most precious resource, inspections should be carefully planned to accomplish a definite purpose.

Types. Announced inspections are used to bring the unit up to a specified performance level by the inspection date. Unannounced inspections are used to measure the unit's normal performance. Announced inspections are best suited for control of one-time-only activities, such as the inspection of a building before turnover or the inspection of a new property book. Unannounced inspections are best suited for control of continual tasks or procedures, such as maintenance or the utilization of workers on a job.

Uses. Both types of inspections are important to the construction supervisor. For example, if a unit is responsible for construction of a fixed bridge, the commander might announce an inspection to check placement of the piers and abutments, while inspections to ensure that safety procedures are being followed would not be announced in advance.

DELEGATION OF INSPECTION AUTHORITY

Inspection is intended to keep the commander informed, and teach, guide, and compel things to happen as planned. Where someone other than the commander is delegated the task of inspecting, instructions must be issued by the commander as to the authority of the inspecting party. These instructions must define if the inspecting party can require work to be done according to specifications and plans and/or to issue stop orders.

Although no formal inspection organization is found in an engineer company, the commander must select personnel for training as inspectors. The work force in the company is usually spread thinly, and trained inspectors are not usually available. Since a thinly spread force is very difficult to control, a commander who spends most of the time making personal inspections will not be able to devote enough time to other functions of command. For these reasons, training of inspectors should be a priority item.

INSPECTION OBJECTIVES

At the construction site the supervisor should inspect performance in the following categories (see figure 5-1, Inspection Checklist):

Construction.

Progress (As scheduled). Compare construction progress with the CPM schedule. Are critical activities on schedule? Are delays in noncritical activities likely to cause a project delay?

Conformance (As specified). Does construction conform to the plans and specifications? Has drainage been provided for? Is there evidence of substandard workmanship?

FIGURE 5-1
INSPECTION CHECKLIST

Categories	Yes	No*	Remarks
Construction:			
AS SCHEDULED:			
1. Critical activities on schedule?			
2. Noncritical tasks accomplished by late finish?			
AS SPECIFIED:			
1. Conform to plans/specifications?			
2. Adequate drainage?			
3. Quality workmanship?			
Utilization of resources:			
WORKERS:			
1. Can commander account for all workers?			
2. Do key NCOs and workers have knowledge of their tasks?			
3. Are workers working or on authorized break?			
4. Maximum utilization of skills?			
5. Adequate supervision of OJTs?			
EQUIPMENT:			
1. Equipment necessary?			
2. Qualified operators present?			
3. Operators using equipment efficiently?			
4. Equipment located efficiently?			
5. Sufficient equipment on site?			
MATERIALS:			
1. Sufficient materials on site?			
2. Arrangement for future deliveries?			
3. Minimal materials handling?			
4. Proper storage?			
5. Minimum waste?			
Maintenance:			
EQUIPMENT:			
1. Current maintenance forms?			
2. Operator maintenance spot checks OK?			
TOOLS:			
1. Assignment of responsibility?			
2. Free from damage and rust?			
3. Used as intended?			
Health and welfare:			
SAFETY:			
1. Hardhat area set up and enforced?			
2. Safety lines?			
3. Insulation and grounding of electrical circuitry?			
4. Sharp instruments or obstacles policed?			
5. Use of earplugs around loud equipment?			
6. Backing guides?			
7. First aid kit?			
8. Adherence to other safety SOPs?			

*Any check in the No column must be explained in Remarks.

FIGURE 5-1 (CONTINUED)
INSPECTION CHECKLIST

Categories	Yes	No*	Remarks
KNOWLEDGE OF TACTICAL SITUATION:			
1. Friendly?			
2. Enemy?			
TRANSPORTATION:			
1. Emergency?			
2. Adequate to and from site?			
3. Suitable for inclement weather?			
DINING FACILITIES:			
1. Warm, clean, sheltered dining area?			
2. Officers and NCOs eat on site?			
3. Good quantity and quality of food?			
LATRINES: (Clean latrines away from dining area?)			
Police. (Satisfactory area police?)			
Other inspection checkpoints (lists):			
*Any check in the No column must be explained in Remarks.			

Utilization of Resources.

Personnel. Does the commander or platoon leader know who is on the site? Are absentees accounted for? Does the commander know what each person is doing? Is everyone working or on authorized break (in order to decide this, the inspector must know the authorized break times)? Are the skills of the workers being utilized to the maximum extent? Are the on-the-job trainees being adequately supervised?

Equipment. Is the equipment on site necessary for transportation or construction? Are there qualified equipment operators on site and are they using equipment efficiently? Is the equipment placed efficiently for construction? Is sufficient equipment on site ready for work? (Appendix E lists equipment and tools needed for the various tasks in the construction process.)

Materials. Are materials on site for the day's work? (Appendix F lists consumption factors for expendable supplies.) Have deliveries of material been arranged for future work? Is materials handling being minimized? Are materials being stored properly to prevent damage or loss? Does the scrap pile indicate excess waste?

Maintenance.

Equipment. Does each equipment logbook have the necessary maintenance forms current and properly filled out? Perform one or two operator maintenance checks as outlined in the appropriate technical manual.

Tools. Has the noncommissioned officer in charge (NCOIC) assigned responsibility for the security, care, and maintenance of all tools? Are the tools damaged or rusty? Does the NCOIC know the procedure for replacing broken tools? Are tools being used as intended? (Pliers are not hammers or wrenches; ripsaws should not be used for crosscuts.) Are all tools under proper, consistent accountability?

Health and Welfare.

Safety. In vertical construction has the NCOIC designated a hardhat area? Are hardhat rules being enforced? Are men who work on poles or elevated trusses or frames wearing safety lines? Is electrical circuitry properly insulated and grounded? Are earplugs used around compressors and other noisy equipment? Are backing guides used to block vehicles? Is there a first aid kit on site? Are other safety SOPs being enforced? Are safety shoes used in appropriate work areas?

Tactical situation. Do all personnel know their actions in case of enemy indirect fire or ground attack?

Transportation. Is emergency transportation from the site immediately available? Is there adequate transportation to and from the site? Is this transportation suitable for inclement weather?

Dining facilities. Is a warm, clean, sheltered dining area provided? Do the officers and noncommissioned officers on the job eat there? Is the quality and quantity of food as good as or better than the food in the base camp dining facilities (to answer this question you must eat there)?

Latrines. Are they clean, adequate in number and design, and away from the dining area?

Area Police. Is the site maintained orderly and policed in a manner that helps rather than hinders efficient work progress?

REPORTS

The commander has limited time and cannot make all the inspections needed to insure effective control. Therefore, reports must be used to supplement personal inspections. The advantage of supplementing inspections with reports is the time saved. The disadvantage is that the commander must see the situation through another's viewpoint.

Reporting System. A good reporting system provides a continuous flow of valuable information to the commander at considerable time savings. A bad reporting system supplies the commander with excess information or misinformation and wastes everyone's time. The following are guidelines for achieving a good reporting system:

Design. Design the reporting system around the commander's needs. Different levels of command have different needs. The same commander has different reporting needs at different times. Since needs change with time and from command to command, reports also must change.

Frequency. The frequency of reports must correspond to the frequency of meaningful changes in the situation. A daily report is meaningless on a situation which changes only monthly or yearly. Reports which contain the same information day after day or week after week are wasted reports. On the other hand, reports must be timely so that the commander can act in time. A meaningful change should be reported promptly whether a report is due or not.

Purpose. Reports are a control device, a system of measurement, not a means of setting standards or policy. Many supervisors think they can force things to happen by forcing their subordinates to report on them. A quarterly report on maintenance does not compel good maintenance; a daily safety report does not guarantee safety. A report which is used to generate "awareness" is a poor substitute for leadership.

Specificity. Since the commander must see the situation through another's eyes, this disadvantage can be largely overcome by a carefully designed, factual, report format. Allowing a subordinate to report percentage completion may give the subordinate wide latitude for interpretation. Making the subordinate report detailed tasks which are completed narrows this latitude considerably. Reports of equipment and man-hour utilization should have specific guidelines so that the subordinate knows how to record each man-hour or equipment hour.

Verification. The commander must make inspections to verify reports. Although the amount of bias in reports can be greatly reduced by setting up an objective reporting system, even the most objective system leaves room for interpretation or even misrepresentation of the facts. A good reporting system may supplement inspection, but reports cannot replace inspections. There is no substitute for direct control.

Report Types. Reports can be designed to control a wide range of performance. Production reports control plant operations, such as quarries, asphalt plants, or prefabrication yards. These reports list production inputs (materials, personnel, equipment hours) and quantities of output over a specific time period. Project costs are controlled by budget reports. Budget reports compare actual to planned expenditures. The most common report in construction is the schedule, which compares actual construction time and resource commitments to planned progress.

The CPM Schedule Report. A detailed CPM schedule is a precise construction control device. An example of a CPM schedule report is shown in figure 5-2 (see also chapter 2 for the project CPM network). Note that there

is very little guesswork involved in the preparation or the reading of the CPM schedule progress report. Activities are either completed, in progress, or not started. Percentage completions are not used. Notes are used to clarify major deviations from the plan. This project report clearly outlines the difficulty in completing activity 11 - 13 if the front loader remains on deadline. This type of report, along with the project plans, provides invaluable data to the estimator. For example, the assembly of these culverts is closer to a 15 man-day job than a 12 man-day job. Also, for this project the use of a front loader saves about 13 man-days of hand labor on activity 9 - 13.

FIGURE 5-2
CPM PROGRESS SCHEDULE FOR INSTALLATION OF TWO CULVERTS
REPORT FOR END OF THE 6TH DAY

Activity no.	Description	Status ¹	1	2	3	4	5	6	7	8
1 - 3(5)	Assemble culvert number 1	Scheduled Actual	2 4	4 4	4 6					
1 - 5	Dig trench number 1	Scheduled Actual	2 2	1BH 1BH 2		x	x	x		
1 - 7	Dig trench number 2	Scheduled Actual	2	1BH 2	1BH 2					
3 - 7	Assemble culvert number 2	Scheduled Actual	2			4 5	4 5	4 5		
5 - 9	Install culvert number 1	Scheduled Actual	2			8 6	x	x	x	
7 - 11	Install culvert number 2	Scheduled Actual	1						8 ²	
9 - 13	Backfill number 1	Scheduled Actual	1				1FL 3 0			
11 - 13	Backfill number 2	Scheduled Actual	0					10 ³		1FL 3
Resources	Backhoe	Scheduled	-	1	1	0	0	0	0	
		Actual	-	0	1	1	0	0	0	
	Workers	Scheduled	-	6	6	4	12	7	4	
		Actual	-	4	6	6	11	5	15	
	Front loader	Scheduled	-	0	0	0	0	1	0	
		Actual	-	0	0	0	0	0	0	

¹Status: 0 = Not started; 1 = In progress; 2 = Complete.

²Work-days committed to 7-11 in the afternoon of the 6th day. Will be recorded tomorrow under day 7.

³Front loader deadlined for days 5 and 6. Three more work-days required on the 7th day to finish 9-13.
BH = Backhoe, FL = Front Loader.

SUPERVISION OF INDIGENOUS PERSONNEL

UTILIZATION

Almost all units, from logistics commands to combat units, can be aided by the utilization of indigenous (local) personnel. The engineer construction unit especially can benefit from the help of local labor. Skilled local tradesmen have experience, which the construction unit may not have, in working with the area's available materials. Local personnel can also help the engineers with such less-skilled tasks as materials transport and apprentice work.

LOCAL SUPERVISORS

The use of local supervisors as first-line managers is important to the successful accomplishment of projects employing local labor. Using capable local personnel as supervisors facilitates control, but great care must be taken in the selection of these supervisors. A poor choice can negate the usefulness of a civic action project, or make further construction operations with local personnel impossible. In any project using local labor, Army managers should remain as inconspicuous as possible.

CONSIDERATIONS

Construction projects involving local personnel must be coordinated with local government and with other US agencies. Wage rates must be set high enough to attract the workers but not so high that the local economy will be thrown into turmoil. If the construction is part of a civic action program, the engineer unit must ensure that the project will fit in with local and US agency planning.

Commitment of US Labor and Equipment. The availability of US labor and equipment to support the project must be examined in the light of changing operational requirements. Often commitments of US resources are not "necessities." Local supervisors can often find alternative ways of accomplishing tasks without the commitment of US equipment or skills.

Capabilities of Local Labor. The materials and technology of the project must be matched to the capabilities of the local force. Failure to consider this in project planning will lead either to projects that are too simple or to projects which do not correspond to the construction and maintenance abilities of the population. Maximum use should be made of local materials and skills.

Length of Projects. If possible, large projects should be constructed by breaking them down into smaller, usable subelements, even if this method of construction results in greater overall effort being expended. Short-duration projects also provide a degree of protection against unforeseen operational requirements. In civic action, the early completion of a project provides visible proof to the citizenry that joint efforts with US units can produce improvements in local living conditions.

CIVIC ACTION PROJECTS

Civic action projects should be designed for maximum community involvement. The need for the project should be determined by the local leadership; the design should be produced by the community when possible, and should always be approved by the community; the construction should be accomplished by local laborers. The role of the engineer unit should be one of technical assistance, materials support, and the occasional commitment of engineer equipment. A civic action project should have the following characteristics:

Maintenance. With any civic action project, a system should be set up during the project planning stage for the maintenance of the project when it is completed. This is particularly important for horizontal construction projects or for equipment transfers.

Development of Local Skills. The ultimate goal of civic action programs should be to increase the skill and self-reliance of the civilian population. Although individual projects should be within local capabilities, they should also teach additional skills.

Stimulation of Additional Projects. In keeping with the building block aspect of skill development, civic action projects should stimulate further projects. A construction materials plant (brick, lumber) is one example of a base project upon which other projects can be built.

QUALITY CONTROL

REQUIREMENT

The control of construction quality in theaters of operations is the responsibility of the project supervisor. Quality control includes planning, designing, and monitoring the construction process to achieve a desired end result. During the planning phase, control is achieved by the proper application of network analysis (CPM), scheduling, and estimating. Designing a project for quality involves choosing the proper configuration, material, equipment, and personnel to achieve the construction. The construction monitoring steps require adherence to standard procedures of construction, established supervision practices, and accepted testing methods. Quality control in military construction is needed for many reasons. The basic objective of quality assurance, however, is to provide a safe, functional, and enduring project with an acceptable appearance.

GUIDANCE

The supervisor must know and apply standard practices to provide guidance to adequately control the various operations involved. Since military construction operations are varied and detailed, this manual describes only general quality control measures. The following paragraphs provide supervisors with examples for developing and using control measures on specific construction projects.

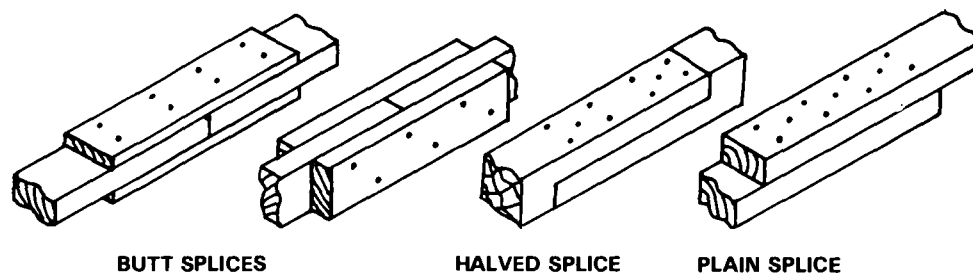
LUMBER

Different types of timber have varying construction and carpentry characteristics. One type is often better suited for a particular job than another. Lumber type and size are usually stated in the construction plan. For more detailed information, consult the appropriate carpentry manual.

Joints. Scan all connections at angles for proper and smooth fit. Check right-angle joints for accuracy with a carpenter's square. End-grain sections are critical and should be examined for splits. Generally, eightpenny or tenpenny nails are used for all types of joints.

Splices. Lumber construction with splices must be as strong as a single timber of equivalent length. To ensure adequate strength, analyze the types of stress on linear connections (figure 5-3). Compression stress may be neutralized by butt and halved splices. Square and plain splices benefit members in tension. Connections subject to bending moments are controlled with combinations of tensile and compressional splices. Check splices to be sure that stresses are counteracted by correct splice type.

FIGURE 5-3
COMPRESSION, TENSION, AND BENDING SPLICES



Fasteners. There are six different classes of fasteners in timber construction—nails, screws, bolts, driftpins, corrugated fasteners, and timber connectors. Nails should be driven at a slight angle for utmost strength. As a rule, the nail should be embedded two-thirds of its length through the piece to be fastened and one-third through the anchoring member. Check construction for adequate nail usage. All screws should be emplaced using starter holes that are less than the diameter of the screw and approximately two-thirds its length. Washers should be used in construction with bolts because without protective washers overtightened bolts can damage the lumber's surface.

Foundations. Wooden piers or columns should be treated with a protective coating to guard against decay. Check piers for 6- to 10-foot spacing. When the piers extend 3 feet above ground, use bracing (figure 5-4).

Framing. Pier connections should have sill reinforcement consisting of single heavy timbers or of two or more timbers. The strength of the girders

relates directly to the square of the span length. If two spans are used, one twice the length of the other, the girder for the longer span should be four times stronger than the other. Nail sizes for two-member girders are sixteenpenny; for four-member girders, twentypenny or thirtypenny. Nails are driven $\frac{1}{2}$ inch from top and bottom with spacing of 24 inches. Girders should be tested (for trueness) with a straightedge. All girder joints should be staggered for strength and durability (figure 5-5).

FIGURE 5-4
BRACED PIERS, SILLS, GIRDERS, AND JOIST CONSTRUCTION

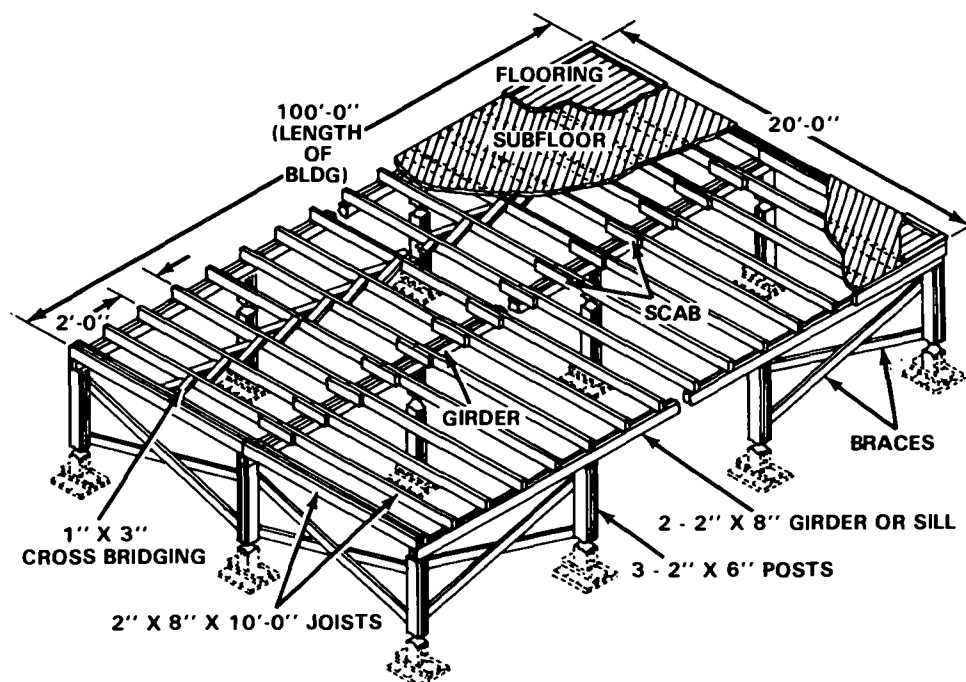
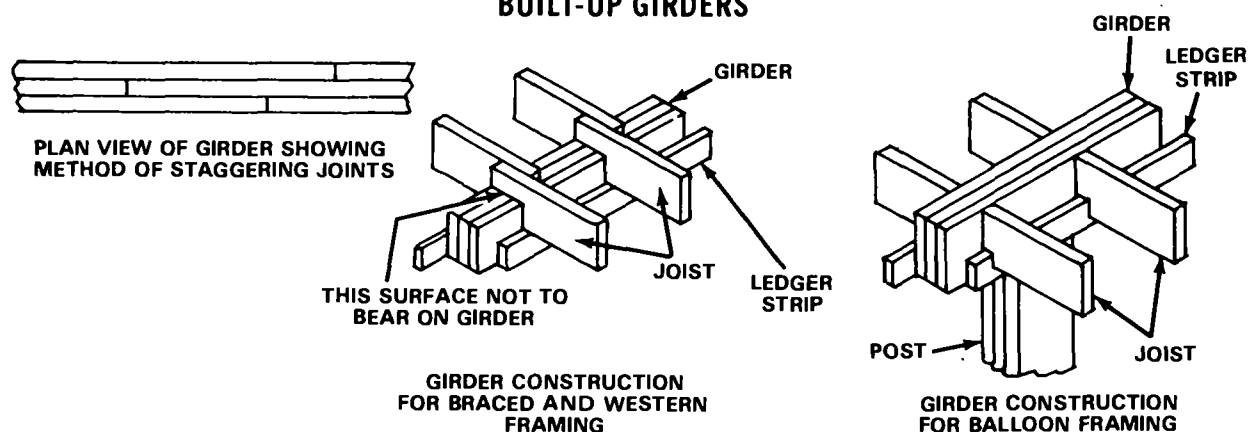
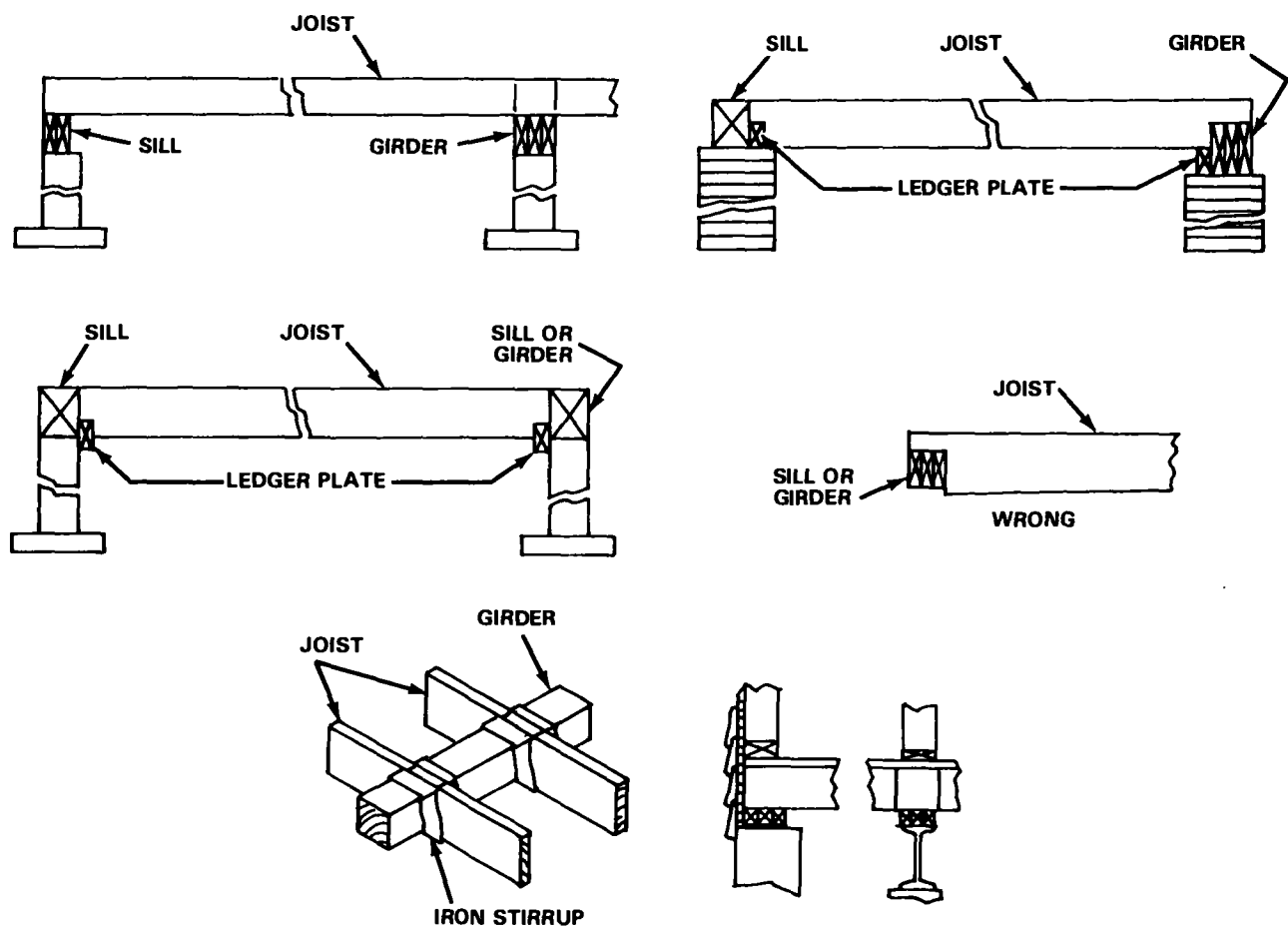


FIGURE 5-5
BUILT-UP GIRDERS



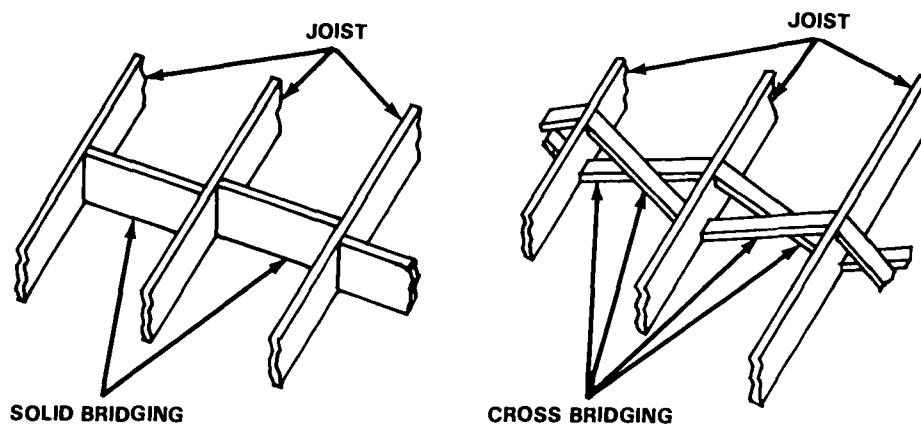
Floor Joists. Floor spans over 10 feet require joists of 2 inches by 8 inches or greater. Usually, joist thickness is 2 or 3 inches and depth is restricted by load conditions. Check the spacing interval to be sure it is no greater than 24 inches center-to-center. In connecting floor joists to girders or sills, use ledger plates with foundations of pier or column type. The joist must not be notched more than one third of its depth in the plate-sill connection (figure 5-6).

FIGURE 5-6
JOIST CONNECTIONS



Floor Bridging. For every 8 feet of span length, one line of bridging must be constructed (figure 5-7). The bridging is toenailed to the joists with at least two tenpenny nails. The bottom of the bridging is not nailed until the rough floor is laid, to facilitate joists adjusting to final position. The bridging is generally 1 inch by 3 inch material.

FIGURE 5-7
FLOOR JOIST BRIDGING



Walls. Corner posts are built up with two or three layers (figure 5-8). When a partition meets an outside wall, T-posts are used to provide area for nailing the inside finish (figure 5-9, on page 5-16). Studs are spaced 12, 16, and 24 inches center-to-center depending on building and finish type, although TO construction standards for temperate climates permit spacing of up to 5 feet. The studs are fastened by two sixteenpenny or twentypenny nails through the top plate. Girts are the same width as the studs so they will be flush. Girts parallel the plates with spacing of about 4 feet. The top plates are the same size as the stud with sixteenpenny or twentypenny nails at all studs and corner posts. The sole plate is at least 2-inch by 4-inch timber, or the same size as the wall thickness. Two sixteenpenny or twentypenny nails are driven at each joist the sole crosses. If the sole runs parallel to the joist, there should be two nails every two linear feet. When horizontally placed, the bridging is about one-half the distance between sole and plate. Posts and walls should be plumb and straightened, using a carpenter's level or plumb bob and a chalk line (figures 5-10 and 5-11, on pages 5-16 and 5-17).

FIGURE 5-8
CORNER POST CONSTRUCTION

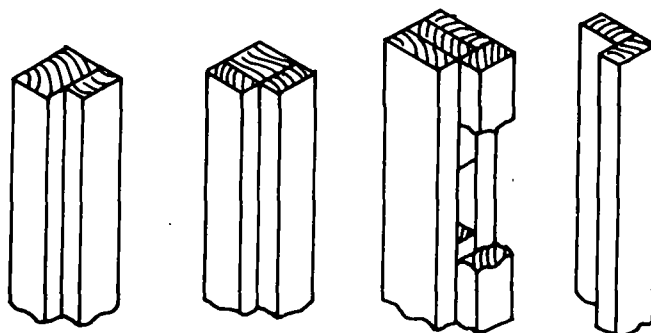


FIGURE 5-9
T-POST CONSTRUCTION

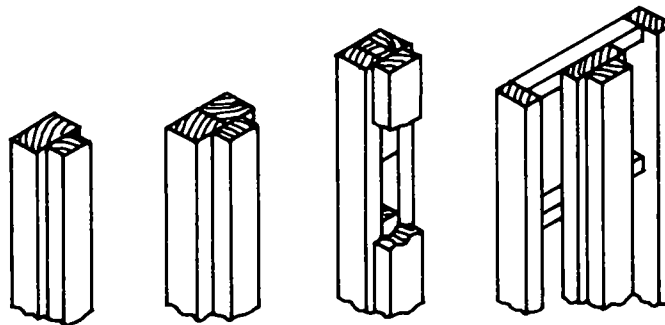


FIGURE 5-10
PLUMBING POSTS

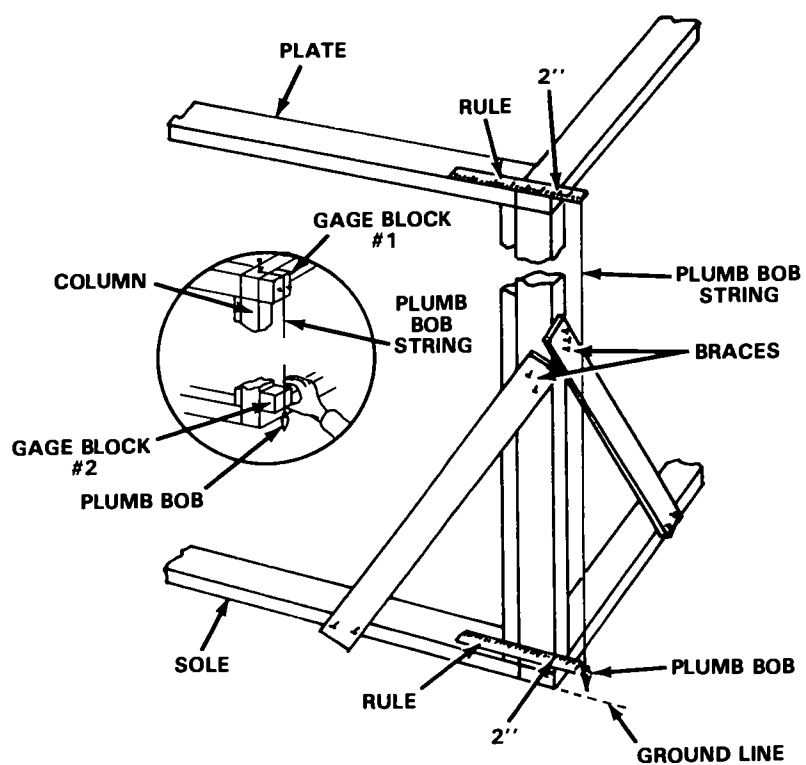
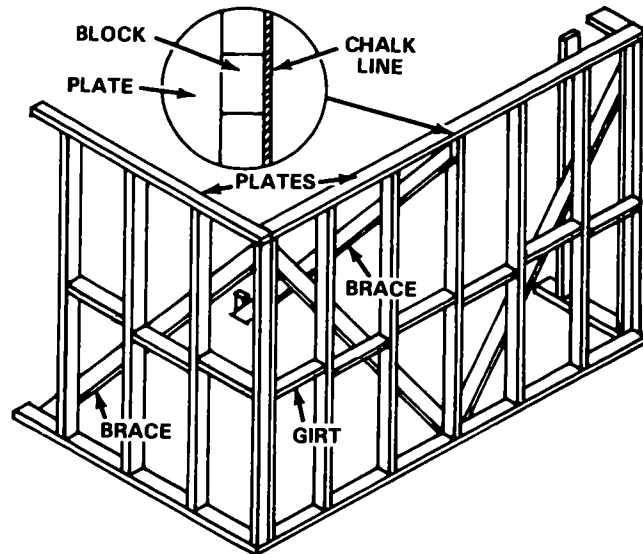


FIGURE 5-11
STRAIGHTENING WALLS



Ceilings. Joists in the ceiling are of the same size as floor joists. Spacing of joists is usually about 16 inches center-to-center. Nailed to the plate and rafter whenever possible, the ceiling joists are lapped and spiked over bearing partitions. The joists are cut flush with rafters.

Rafters. Spacing of 16 to 48 inches is necessary in rafter construction. Measure rafter rise and run with tape to check the specified pitch. The rafters are fastened with sixteenpenny or twentypenny nails and are braced when long spans are necessary.

Openings. Openings (floor, door, roof, and window) are framed by headers and trimmers (figures 5-12 and 5-13, on page 5-18). Door openings should allow at least $\frac{1}{2}$ inch between jamb and framing members in order to allow plumbing and leveling of jamb. Window openings require studding to be cut away and its equivalent strength replaced by redoubling the studs on each side of the opening to form trimmers and inserting a header at top. Wide openings need two headers with trusses added.

FIGURE 5-12
FLOOR OPENINGS

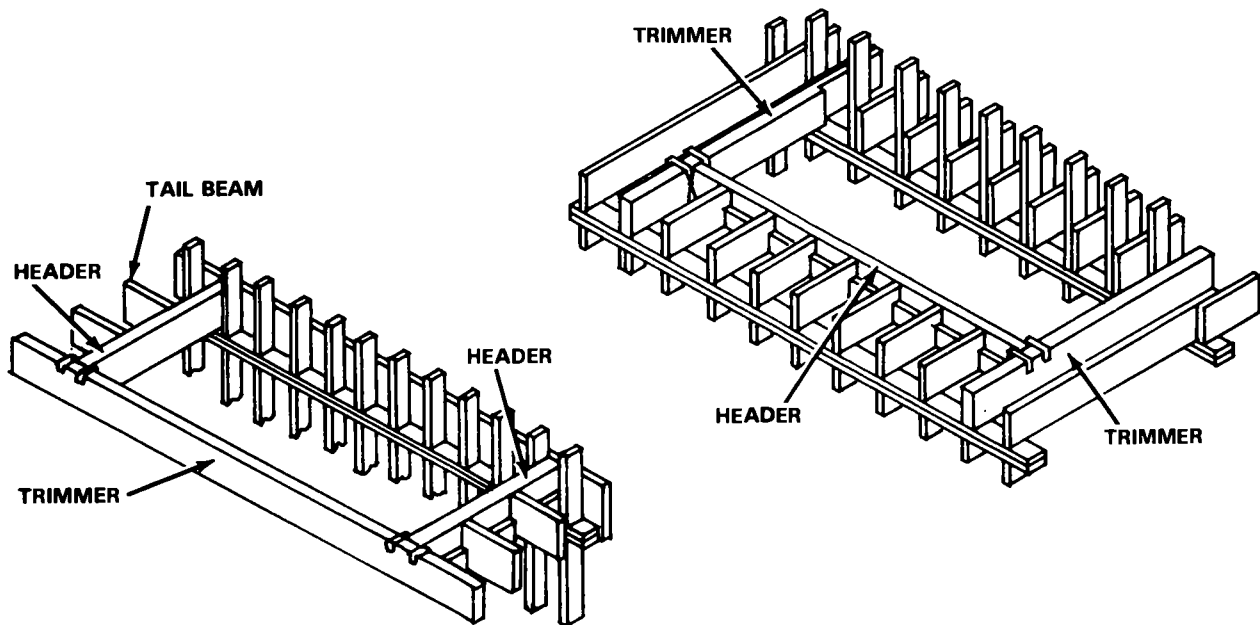
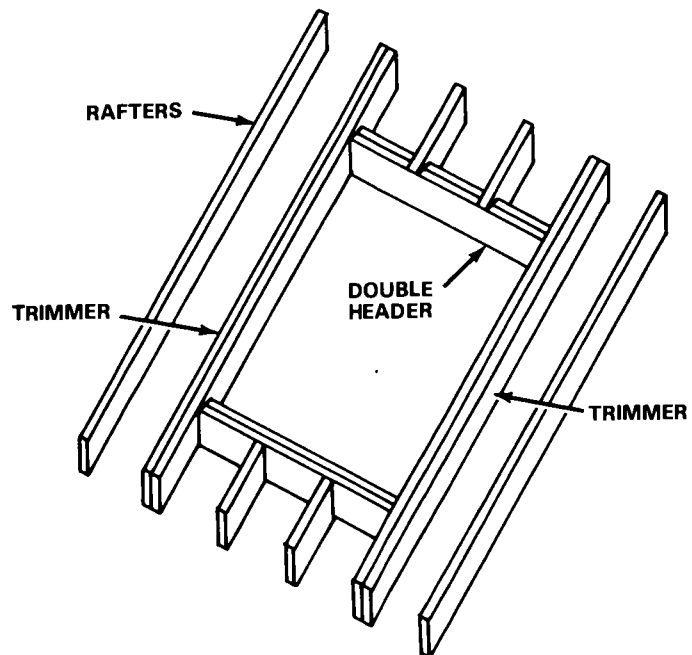


FIGURE 5-13
ROOF OPENING



Steps and Stairs. Step material must be measured to ensure that it is 2 or 3 inches thick and 6 or 8 inches wide. Stringers are at least 2-inch by 4-inch material, and stairways usually contain three sets. The ideal pitch of the stringers is obtained with a rise of 7 inches and run of 10 inches. For adequate headroom, clearance should be a minimum of 6 feet 8 inches.

Floors. The subfloor, when used, is laid diagonally and connected with eightpenny or tenpenny nails. Subflooring 8 inches wide or greater requires three or more nails per joist. Subflooring of greater than 1 inch thickness should be fastened with larger nails. Finish flooring is generally $\frac{3}{4}$ inch thick and $3\frac{1}{4}$ to $7\frac{1}{4}$ inches wide with square or grooved edges. Nails are driven in every joist and are eightpenny size, if the flooring is to support heavy loads and the material is 2 inches thick and 4 to 12 inches wide with only square edges. Stronger flooring is connected with sixteenpenny or twenty penny nails.

Exterior Walls. Sheathing should have no lengthwise gaps and end joints should be placed over studs. Fastening is accomplished with three eightpenny nails if pieces are more than 6 inches wide. Size of sheathing is $\frac{3}{16}$ inch thick by 6, 8, 10 or 12 inches wide. Vertical siding cracks are covered by wood strips called battens which are attached by eightpenny or tenpenny nails. Horizontal siding of the beveled type needs 1-inch overlap at the narrow end and 2 inches at the wide end. The nail is driven at the butt through the narrow portion. Drop horizontal siding, when used as combined sheathing and siding, requires tongue-and-groove lumber with the tongue up and nailed directly into the studs. If sheathing is not used, drop horizontal siding is applied after any opening casings are set. If sheathing is used, building paper and drop siding are applied after opening casings are set.

Concrete Form Construction. The FM 5-742 contains adequate designs for all types of required forms. Since forms tend to lose their shape after the concrete has been placed, measures must be taken to restrict spreading of forms. Generally, construction sheathing of 1-inch thick material is required for footing forms. It should be nailed to vertical cleats of 2-inch material spaced on 2-foot centers. All footing panels are tied together from opposite sides with Number 8 or 9, soft, black, annealed iron wrapped around center cleats. All nails are driven halfway for easy removal. Forms greater than 4 feet square require 1-inch by 6-inch boards nailed across the top to prevent spreading. Wall footings should have spreaders nailed at intervals to maintain desired footing width. Check for adequate spreaders and ties around forms to eliminate spreading. Ensure that provision is made for removal of spreaders after concrete is placed.

CONCRETE

Take care to provide dry storage areas for cement. Before use, check cement for hard lumps that indicate partial hydration which causes reduced quality. Laboratory tests should be made on the mixing water to determine impurities, such as sulfates, that detract from concrete properties. If laboratory facilities are not available, water that is suitable for drinking is generally suitable for concrete production.

Structures. Portland cement is manufactured to meet several different qualities established by the American Society for Testing and Materials (ASTM). To assure the structural soundness of concrete structures, follow guidance in FM 5-742 for matching cement type with a particular structure.

Inspection of Aggregate. Aggregate should be visually inspected for contamination by dirt, clay, or other organic matter, and weaknesses such as cracks. Practical aggregate shape calls for particles that are more rounded or cube-shaped than rough or sharp. Experience shows that either extremely fine or coarse sands (determined by visual inspection) are objectionable. Stockpiles of aggregate should be examined for segregation and contaminating features.

Tests. When portland cement admixtures are specified, tests to assure desirable mixes are performed. There are three such tests—pressure, volumetric, and gravimetric. Discussions of these tests and other cement component checks are contained in FM 5-742.

Portioning of Concrete Mixtures. Three procedures are available to determine amounts of each component of a concrete mixture. These are known as the book, trial batch, and absolute-volume methods. All are adequate, although the book method may require adjustment in the field. Initial mixes should be sampled for appearance to determine whether proper proportions are present. Periodic checks to maintain quality should continue through the mix cycle. A concrete mixture which contains the correct amount of cement and sand will fill all spaces between coarse aggregate particles with mortar when troweled lightly. If voids between coarse particles are not filled after light troweling, the concrete mixture is deficient in cement-sand mortar. Spot inspection of all scales and measuring devices should take place every shift to assure accurate proportions. Check weights and volumes should be utilized regularly. Concrete consistency is generally measured by a slump test and checked against specifications. Proper methods for completing the slump test are outlined in FM 5-34 and FM 5-742.

Concrete Construction Joints. Check the effects of planes created by work from different days. Joints should be strategically placed in zones that will cause a minimum amount of weakness in the structure. These zones are located where shearing stresses and bending moments are small. The joints may also be reinforced by support from other members. Prepour inspections should be made to check for suitable measures of reinforcing joints with keyways, V-joints, or steel bars.

Expansion and Contraction Joints. Check for location of expansion and contraction joints where there is a change in thickness, at offsets, and where the concrete will tend to crack if shrinkage and deformations due to temperature are restrained. Expansion joints should be observed for adequate filler of cork or premolded mastic. Generally, there should be expansion joints every 200 feet. Contraction joints are at 30-foot intervals or less. Dummy contraction joints are joints with no filler or with a thin paint coat of asphalt, paraffin or other material to break the bond. These joints are to be at a depth of one-third to one-fourth times the thickness of the structure.

Handling, Transporting, and Placement. Poor handling and transporting techniques can cause segregation of concrete. Mixes should be observed at regular intervals for mix separation resulting from poor delivery methods. Avoid placement drops of greater than 3 to 5 feet by using chutes, baffles, or pipes. Individual pourings of concrete layers should never exceed 20 inches of thickness (except in columns or piers). Check consolidation of concrete by observing the surface of the structure after forms are removed. A smooth finish indicates that proper vibration is being accomplished. Inspect finish quality by viewing surface characteristics. Small tears in the surface indicate screeding (smoothing) was too fast or performed without a bottom metal edge on the screed tool. If a smoother surface is desired, floating should be checked. Excessive floating is indicated by the appearance of excess water and mortar on surfaces. Further evidence is revealed when this fine material scales and tears. If the surface of the concrete is not as dense as specified, troweling may be tried. To check the efficiency of troweling, observe the surface. If the trowel leaves the concrete skin free of all marks and ripples, the process is satisfactory.

Curing. Take steps to assure that curing is proceeding properly and that a standard curing method is being followed. All of the standard methods must be used to achieve specified strength during the concrete curing period (see FM 5-742).

Reinforced Concrete Construction. If concrete will have to withstand tension as well as compression, slender steel reinforcing bars are necessary. Reinforcing steel has been specified by ASTM with minimum yield strength of 40,000 pounds per square inch, 50,000 pounds per square inch, 60,000 pounds per square inch, and 75,000 pounds per square inch. The grade mark of the steel is stamped on the standard bars. For example, a "40" will be located on a bar that has a yield strength of at least 40,000 pounds per square inch. Plans will call for the minimum yield strength desired for particular structures. Hooks to reinforce areas are labeled by type in structure construction drawings. Care should be taken to check hook placement and type. All splices of bars are overlapped and tied and should be staggered. Before placing concrete, check reinforcing pads for anchorage and correct if required. Bar intersections in flooring reinforcement should be tied with one turn of wire at frequent intervals to create a steady network.

Clear distances between parallel bars in columns should be measured and should be at least one and one half times the bar diameter. Reinforcements are usually kept a minimum distance from outside concrete surfaces. Check for conformance.

MASONRY

The strength of all masonry lies in the mortar that bonds the structure. Specific jobs require designated types of mortar mixes and steps must be taken to provide the designated category. A guide to favorable mixes is tabulated in FM 5-742. Mixing time can affect quality and should be reviewed to guarantee the standard limits of at least 3 minutes of machine mixing are met. As in concrete mixing, mortar mixing requires accurate batching. Examination of the measuring processes should reveal any poor techniques, faulty equipment, and improper methods.

Materials. Concrete block, brick, and tile used in masonry construction are specified in plans to meet strength and size requirements. Details of block types and sizes are in FM 5-742. Rubblestone is an expedient raw material. Size has no bearing, although roughly squared stones are better. Rocks chosen should be strong and durable, such as limestone, sandstone, or granite.

Construction. The line, level, and plumb of all construction must be true and measured regularly with straightedge, plumb line, and level. All joints should be filled with mortar and adequately compacted. Masonry joints should be a uniform thickness and approximately $\frac{3}{8}$ inch thick. First levels of all masonry work should be constructed with extreme caution to assure alignment, level, and plumb throughout the structure.

Methods. Rubblestone wall quality depends on the stone placement. Each stone should be placed on its broadest face; the larger stones should be at the base of the structure. Care should be taken that all voids between stone are filled with mortar. Bond stones that horizontally pass all the way through a cross section of the wall should occur at least once in every 10 square feet of wall. Usually, stone walls are aligned by sight. However, if exactly plumb and level stone walls are required, checks with plumb line and level must be made.

STEEL

Inspect material for bent or twisted pieces. If the strength of a member is questioned, a bent piece of steel should not be straightened, but used as stock to be cut for shorter lengths. Material with short kinks or buckles or material that shows surface cracks at point of deformation should not be used.

Type and Size. Fabrication of steel structures is restricted to certain type and size members which are noted on construction plans. The designated members should be identified by measuring the length and cross-sectional dimensions. The appropriate length and size will be given in the plans, so

that a cross check of all material can be made. To assure proper placement, each member can be marked with paint or chalk.

Connections. There are four different ways to connect steel structural members—bolts, rivets, pins, and welds.

Bolts. To determine if bolts of the proper length are being used, check the length of thread that extends beyond the nut after tightening. This length should be about $\frac{1}{4}$ inch. Bolts should be tightened with a structural offset wrench, first tightening the nut and then applying one last twist on the wrench. To avoid overstressing the bolt, do not use pieces of pipe or other extensions to wrench handles. If the structure is permanent, check to be sure the threads beyond the nut are hammered down. (All bolts should be coupled with at least one lock washer under the nut.) If a pneumatic impact wrench is used, check adjustment of the wrench for proper tightening of bolts by measuring performance with a torque wrench. (Torque specifications are in the plans.) Inspect the connecting process to ensure that parts being fastened are aligned with driftpins before bolts are installed.

Rivets. Examine rivet connections for inadequate lengths, indicated by either capped heads when too long or underformed heads when too short. A table of recommended lengths of rivets is given in TM 5-744. Pieces to be fitted with rivets must be set up with bolts and tightened before riveting. Inadequate fastening by rivets is usually an indication of improper setup. Proper heating of the rivets is indicated by a light cherry-red color. To test for loose rivets, touch a finger or a small piece of metal to one side of the finished rivet. Tap the other side lightly with a hammer. An adequate joint will not transfer vibration to the finger or metal. To inspect for burning of the rivets, inspect rivet head for pitted surfaces.

Pins. Inspect pin connections for holding mechanisms such as cotter pins or threaded recessed nuts. Great care must be exercised in boring pinholes and they must be examined for smoothness, straightness, and perpendicular alignment to the member axis.

Welds. Weld joints must be continuously checked by a qualified inspector. Finish welds are examined for undercut, overlap, surface checks, cracks, and other defects. To become better qualified on criteria that separate a good weld from a bad one, compare the actual weld products to variations of welds. A procedure for training inspectors and welders involves varying the three welding parameters one at a time. These parameters are current, voltage, and speed. Comparing the welds produced with varied parameters provides a basis for determining when faulty welding practices have been used. The TM 5-744 illustrates surface appearance of welds made under varying operating conditions. Properly welded joints should be uniform in appearance with evenly deposited weld metal. Fusion of the base metal at the point of contact of the weld is important and should be complete in a good joint.

PLUMBING MATERIALS

Military plumbing supplies are divided into five categories: cast iron, iron and steel, copper tubing, bituminized fiber, and asbestos cement. The plumber has little choice in the kind of material used since it is ordered by someone else. However, a few basic criteria dictate acceptable grade of the plumbing supplies. Since cast iron, iron and steel pipe are subject to corrosion, they should be checked for rust upon receipt and stored in a dry place. Also, cast iron is extremely brittle and should be checked for splits and cracks. Copper tubing is the most desirable material for water distribution systems. However, it has a tendency to split and should be checked.

Cutting. The steel pipe cutting wheel should be checked visually for nicks or burrs. After the steel pipe is cut, following standard procedure, it must be reamed to remove the inside burr and filed to remove the outside burr. Cast iron pipe is usually cut with a machinist's cold chisel and hammer. Inspection of the cut cast-iron pipe should show an even break around the circumference. If the break is not even, check to see that the cast-iron soil pipe is not being cut too fast. Copper tubing is cut with a pipe cutter or hacksaw. If a pipe cutter is used, check the cutting wheel for nicks or burrs. If a hacksaw is used, see that the blade is fine-toothed (24 teeth per inch). Also, cutting with a hacksaw should only be accomplished with a miter box or a jig (a board with a V-groove for holding the tubing). Make final visual inspection of the finish cut to assure no burrs remain and that the tubing is not out of round. Fiber pipe is cut with either a crosscut or a rip handsaw. Inspection of the cut should reveal a square and shred-free cut. To ensure a quality cut in fiber pipe, a miter box should be used.

Joining. Steel pipe must be threaded before joining. Before threading, check to ensure that die and guide are the same size and correspond to the size of the pipe being threaded. Always inspect the threader to ensure that it has sharp dies free from nicks and wear. A quick check of a pipe joint is made by examining the number of threads. If the pipe was threaded to the correct length, two or three threads will show on the pipe beyond the face of the fitting. Cast-iron joints are made by caulking with lead or oakum. Inspect quality of cast-iron joints for poor coverage and cracked pipe. To make sure that a copper tubing joint has been properly soldered, check the connection for a complete line of solder around the joint. Asbestos cement pipe joints may be checked for quality by a special feeler gage. The gage is inserted between the sleeve and the pipe. The proper spacing of the rubber rings and any kinks are indicated by the gage.

Bending. In special cases, bending iron pipe may be more advisable than placing additional fittings. Check to determine which method is more practical or less difficult. Two criteria control bending—configuration and radius. It is desirable to leave a straight section between bends rather than to make a direct reverse bend.

SOIL

Knowledge of soil characteristics is vital to the quality construction of military roads and airfields. To determine soil properties, several identification procedures known as classification tests have been designed.

Classification. Classification is an engineering tool that provides the construction supervisor with information such as proper soils for base course and subgrade. Procedures for these tests (field identification, California bearing ratio, dry density, etc.) are discussed in TM 5-330. Once the soil has been classified (verified by laboratory tests when practical), TM 5-330 may be used to arrive at the pertinent factors of that particular soil.

Construction Control. The construction sequence for military roads and airfields may be listed as layout, clearing and grubbing, stripping, drainage, earthwork, subgrade preparation, base course preparation, and wearing surface preparation.

Layout. During the layout phase, a survey crew will place construction stakes along the proposed roadway or airfield. The construction stakes indicate alignment, cut, and fill. Before any other construction occurs, the supervisor must double-check the survey work with the design. The information on the stakes such as elevations, slope ratios, and cut-fill amounts may be compared to specifications on the design for accuracy.

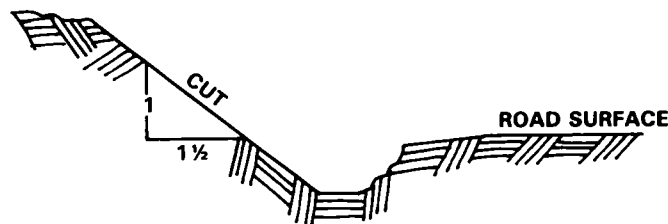
Clearing and grubbing stages. The control of clearing, grubbing, and stripping stages of construction assures that all stumps, boulders, vegetation, and material above surface are removed so construction will not be hindered.

Drainage. Probably the most important aspect of road and airfield construction is drainage. A supervisor must be aware of and prepare for adequate drainage throughout all the construction process. Soils may be divided into three groups of different drainage characteristics. Well-draining soils are sands and gravel such as those classified as GW, GP, SW, or SP. Open ditches may be used in these soils to achieve effective drainage. Poorly draining soils are silts and clays such as ML, OL, MH, GM, and SM categories. Subsurface drainage systems should be utilized. The final class is impervious soils such as GC, SC, CL, CH, and OH groups. These type soils require overdesign of subsurface drainage to be effective. Generally, a supervisor may expect poorer drainage on a site with coarse-grained soils than with fine-grained soils. A good rule when considering construction drainage is to maintain at least five feet between the construction and the top of groundwater. This distance may be obtained by either raising the work level or lowering the groundwater table. Natural drainage should be used, whenever possible.

Earthwork. In construction, earthwork involves cuts and fills. The standard cut for highway or airfield construction is 1½:1 which is suitable for favorable soils (figure 5-14, on page 5-26). Favorable soils are cohesive, sandy or gravelly soils or dry, cohesionless soils.

However, if the depth of the cut exceeds 20 feet, slope should be based on experience in that particular area, stability analysis (described in TM 5-330), or excavation of trial slopes. Generally, if the cut exceeds 20 feet, the slope ratio may have to be reduced. Because of their erosion characteristics, sandy or loamy soil cuts should never be greater than two to one. Slopes steeper than the standard cut can only be planned in areas of rock, in dense, sandy soil interspersed with boulders, or in loess. When construction is to occur in loose, saturated sand, soft clays, or weathered rock areas, caution must be used in making standard cuts. Usually the slopes will have to be flattened, drainage improved, or retaining walls constructed. The standard slopes for a fill in military construction vary from $1\frac{1}{2}$:1 to 3:1. The slope selected is based on the soil embankment characteristics which are given in TM 5-330. Soils used in construction fills generally should be coarse-grained. Care should be taken during stripping to ensure that all organic material (usually one foot of top soil) is removed. Organic material is not suitable for construction material because it cannot be compacted to achieve design specifications for strength and stability. Control generally takes the form of field checks of moisture and density to determine whether the specified density is being attained (see TM 5-330). Adjustments in the rolling process and moisture additions to achieve the specifications must follow the density measurements if out of limits.

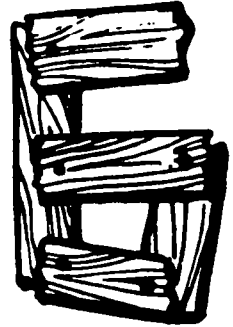
FIGURE 5-14
CUT-SLOPE RATIO IN FAVORABLE SOILS



Subgrade preparation. Soil materials such as expansive clays, silts, and strength-losing clays cannot be compacted to design densities, and proper procedures for handling such material must be used. Acceptable subgrade material preparation is controlled to a minimum modified AASHTO (American Association of State Highway and Transportation Officials) requirement by ensuring that dry density and moisture content is adequate.

Base preparation. Information relative to subbase and base construction for specific construction materials is contained in TM 5-330. Wearing surfaces of military roads and airfields are classed in three groups—rigid, bituminous, and natural. The design and the requirements of construction determine which material will be used.

Chapter



Earthmoving Operations

EQUIPMENT

Earthmoving may include site preparation, excavation and backfill, dredging, and preparing base and subbase. The type of equipment used can have a great effect on the man-hours and machine-hours required to complete a given amount of work. Before estimates can be prepared, a decision must be reached on the best method of operation and the type of equipment to be used. Equipment selection should be based on efficient operation and availability of equipment. It is best to use any available equipment that can reduce the amount of manual labor required. Since most earthmoving operations can be done by machines with operators, manual labor should be avoided.

SITE PREPARATION

This includes clearing and grubbing operations such as removing, piling, and burning trees and brush, removing stumps, and loading and hauling cut trees and brush. Site preparation also includes cut-and-fill earthmoving operations, removal of existing asphalt and concrete structures (paving, walks, and curbs), excavating and hauling from cut areas, as well as spreading and compacting into fill areas.

EXCAVATION AND BACKFILL

This includes trenching and ditching, digging bell holes, excavating for footings and foundations, general excavation, and removing excess earth. It also includes trimming and grading, water removal, shoring and bracing, backfilling and compacting, excavating and hauling fill, spreading and compacting fill, and general grading.

DREDGING OPERATIONS

This includes preparation of spoil area for dredged material as well as construction of dikes when required, setting and connecting discharge lines from dredge, dredge operation, barge operation, and disconnecting and removing discharge lines. It also includes underwater excavation with a dragline or clamshell, hauling dredged material by truck or barge, and disposal of material.

BASE AND SUBBASE PREPARATION

This includes grading and smoothing, excavating, loading, hauling, spreading, rolling, sprinkling, and fine-grading selected material to form the base and/or subbase. A factor for compaction (see table 6-9, on page 6-10) should be added to the computed compacted quantity to obtain the quantity of loose material which must be handled.

GRAPHIC AIDS

Graphic aids are useful for estimating production rates for any repetitious construction operation that has several definable variables.

The variables may be arranged in graphic form as shown in figure 6-1. The graphic form uses the direct reading capability of the nomogram or nomograph to show relative effect of the variables on production.

Nomograph. Seven variables are incorporated into one graphic representation in the earthmoving nomogram (figure 6-1). Two variables were fixed: capacity at 5 cubic yards per truck and time at 10 hours per day. Time delay per trip, distance, speed, number of trucks, and total volume hauled per day were then progressively locked into the nomograph to form this unique estimating tool.

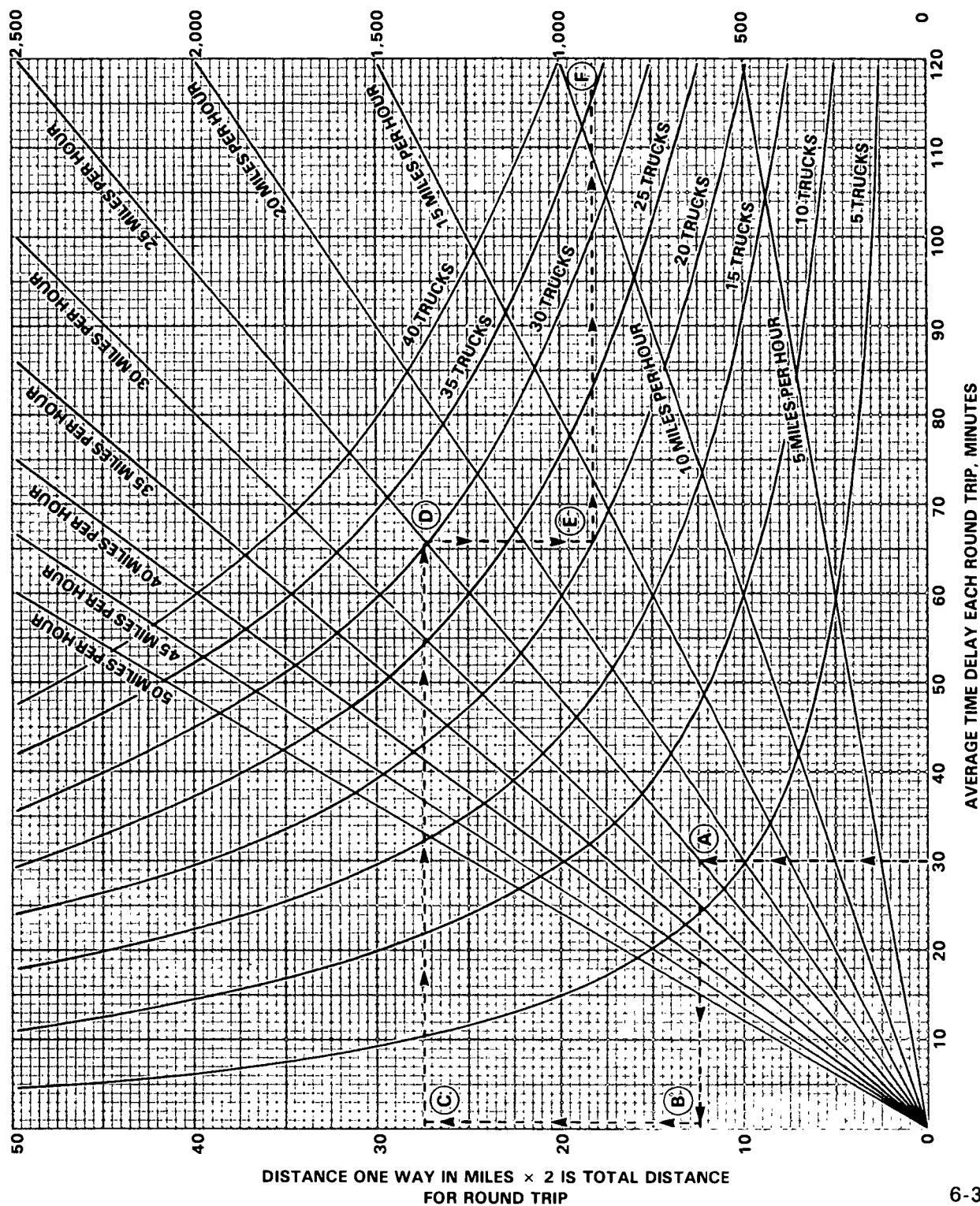
Example. Find the volume of earth in cubic yards hauled per 10-hour day in 20 trucks, each averaging 5 cubic yards per trip, and with an average time delay of 30 minutes, average speed of 25 miles per hour, and an average haul distance of 7.5 miles.

Using the nomograph (figure 6-1) to find the volume, follow the broken line 30 - A - B - C - D - E - F.

- Average time delay per truck per trip for loading, dumping, maintenance, and contingency during 10-hour workday is 30 minutes. Enter nomograph at average time delay of 30.
- Average speed is 25 miles per hour. Project average delay time of 30 to 25 miles per hour - A.
- Read across to distance equivalent - 12.5 miles - B.
- Average haul distance is 7.5 miles. Double for round trip. Combined distance, D, is 27.5 miles - C.

FIGURE 6-1
EARTHMOVING NOMOGRAPH

FOR 5 CUBIC YARDS/TRUCK/10-HOUR DAY



- Project to 25 miles per hour (speed) - D.
- Twenty 5-yard trucks are used - E.
- Read across to production line, V - cubic yards hauled is 910 cubic yards per day - F.

Check by computation:

t = Time delay/trip, minutes	= 30 minutes
S = Speed	= 25 miles per hour
d = Distance one way	= 7.5 miles
N = Number of trucks	= 20 trucks
Q = Quantity per truckload	= 5 cubic yards
H = Hours/day haulage	= 10 hours/day
V = Volume hauled/day, cubic yards	= (To be determined)

Then,

$$V = \frac{S}{S(t/60) + 2d} NQH$$

$$V = \frac{25 \text{ miles per hour}}{25 \text{ miles per hour (30 minutes/60 minutes per hour) + (2 x 7.5 miles)}} \times 20 \text{ trucks} \times 5 \text{ cubic yards per truck} \times 10 \text{ hours per day}$$

$$V = \frac{25 \text{ miles per hour}}{27.5 \text{ miles}} 1000 \text{ cubic yards per day}$$

$$V = 909.09 \text{ cubic yards per day}$$

or 910 cubic yards per day

ESTIMATING TABLES

Tables 6-1 through 6-16, on pages 6-5 through 6-8, may be used in preparing machine and man-hour estimates for earthmoving. These tables are off-site estimating data, not exact figures. Since the variables affecting earthmoving are many, much consideration should be given to situations and conditions varying from the norms these tables are based upon. A table on soil variation conversion factors (table 6-7, on page 6-9) and a table on boom swing angle conversion factors (table 6-8, on page 6-9) should be used when necessary. These are only two variables of many that must be considered. The prevailing conditions and situations will always govern earthmoving estimates. Other conversion factors are listed in Tables 6-10 through 6-14, on pages 6-8 through 6-9.

TABLE 6-1
SITE PREPARATION—CLEARING AND GRUBBING

Work element description	Tree diameter in inches	Equipment	Unit	Hours/Unit Rates in machine-hours
Machine work:¹				
Light clearing		D7F dozer	1,000 square yards	.75
		D8K dozer	1,000 square yards	.45
Medium clearing		D7F dozer	1,000 square yards	1.8
		D8K dozer	1,000 square yards	1.1
Difficult clearing: (For trees and stumps, good con- ditions, good trac- tion no steep slopes.)	8 - 12	D7F dozer	10 each	.8 - 2.5
		D8K dozer	10 each	.5 - 1.5
	13 - 24	D7F dozer	10 each	3. - 5.
		D8K dozer	10 each	1.8 - 3.
	25 - 36	D7F dozer	10 each	5. - 10.
		D8K dozer	10 each	3. - 6.
Hand work:²				Rates in man-hours/unit
Light clearing		Axes, brushhooks, hatchets, machetes	100 square yards	2.5
Medium clearing		Axes, cross saws	100 square yards	5.
Cutting large trees: Removing branches, cutting into short lengths	8 - 12		each	9. - 12.
	13 - 18	Crew = 4 workers	each	12. - 16.
	19 - 24		each	20. - 24.
	25 - 36		each	26. - 30.
	8 - 12	Chain saws, axes	each	2. - 3.
	13 - 18	Crew = 3 workers	each	3. - 4.
	19 - 24		each	5. - 6.
	25 - 36		each	6. - 8.
Removing stumps	8 - 12	Picks, shovels, axes	each	8.
	13 - 18	Crew = 3 workers	each	10.
	19 - 24		each	12.
	25 - 36		each	15.
Blasting trees		Demo	10 each	1.5
Blasting stumps		Demo, sledge hammer, priming stake. Crew = 3 workers	each	1.
Piling and burning		Labor	100 square yards	.8

¹Typical crew: 1 crew leader, 1 dozer operator, 2 to 5 workers with chain saws and axes cutting and trimming.

²Typical crew: 1 crew leader, 4 to 8 workers with brushhooks and axes, 1 to 2 workers with portable chain saws, 2 to 5 workers burning.

TABLE 6-2
SITE PREPARATION—EARTHMOVING, CUTTING AND FILLING

Work element description	Equipment	Unit	Hours/Unit
Machine work:¹			Rates in machine-hours
Excavate and load into trucks	Power shovel - $\frac{3}{4}$ yard ²	1,000 cubic yards	9.
	Dragline - $\frac{3}{4}$ yard ²	1,000 cubic yards	12.
	Clamshell - $\frac{3}{4}$ yard ²	1,000 cubic yards	17.
One-way distance: 50 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	3.5
	- 5 yards	1,000 cubic yards	7.
100 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	5.2
	- 5 yards	1,000 cubic yards	10.4
200 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	7.1
	- 5 yards	1,000 cubic yards	14.2
300 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	10.4
	- 5 yards	1,000 cubic yards	20.8
Haul in trucks:	5-ton dump ³	1,000 cubic yards	42.
(Assume approximately 4 cycles per hours)	20-ton dump ³	1,000 cubic yards	17.5
Excavate, load, haul: (Round trip) cycle time:			
3 minutes	18 yard scraper	1,000 cubic yards	3.5
5 minutes	18 yard scraper	1,000 cubic yards	5.6
7 minutes	18 yard scraper	1,000 cubic yards	7.8
10 minutes	18 yard scraper	1,000 cubic yards	11.1
Strip topsoil/stockpile soil, shallow excavation	D7F dozer	1,000 cubic yards	37.
	D8K dozer	1,000 cubic yards	22.6
Spread fill	D7F dozer	1,000 cubic yards	16.
	D8K dozer	1,000 cubic yards	9.6
Sprinkle	1,000 gallon distributor	1,000 square yards	.04
Compact	Sheepsfoot roller	1,000 square yards	.19
	113 inches wide (2 rollers)	1,000 square yards	.39
		1,000 square yards	.58

¹Crew: crew leader and machine operators/dumptruck drivers as required or available.

²See table 6-8 for conversion factors for swing angle.

³To use for other than 4 trips/hour, calculate cycle time and use appropriate proportion.

Example:

Cycle time of 20 minutes = 3 trips/hour. Then
 (4 trips/hour)(42 hours) = (3 trips/hour)(? hour) and ? =
 56 equipment hours/1,000 cubic yards.

TABLE 6-3
TRENCHING, DITCHING AND BACKFILLING

Work element description	Equipment	Unit	Hours/Unit
Machine work:¹			Rates in machine-hours
Trench and ditch excavation	Model 750 ditcher	1,000 cubic yards	2.9
Backfill	Huber grader	1,000 cubic yards	2.
Compact	Sheepsfoot roller	1,000 square yards	.19
	10 feet wide (2 rollers)	1,000 square yards	.39
		1,000 square yards	.58
"V" ditching	Huber grader	1,000 cubic yards	4.
	Huber grader	1,000 cubic yards	6.7
	Huber grader	1,000 cubic yards	11.8
Hand work:²			Rates in man-hours
Excavation (6 feet maximum depth)	Shovels, picks	cubic yard	1.75
Bell holes		10 each	1.
Backfill	Shovels	cubic yard	.75
Tamp	Pneumatic tamp	cubic yard	.7
Shoring walls			
	Excavation depth:		
	5-8 feet	Sheet piling, lumber,	100 square feet
	10-15 feet	nails, hammers, saws	100 square feet

¹Crew: 1 crew leader and operators as required or as available.

²Typical crew: 1 crew leader, 2 to 10 workers excavating, 1 to 2 workers bell holes, 2 to 8 workers backfilling and tamping.

TABLE 6-4
EXCAVATION FOR FOOTINGS AND FOUNDATIONS AND GENERAL EXCAVATION

Work element description	Equipment	Unit	Hours/Unit
Machine work:¹			Rates in machine-hours
Excavate and load into trucks	Power shovel - $\frac{3}{4}$ yard ²	1,000 cubic yards	9.
	Dragline - $\frac{3}{4}$ yard ²	1,000 cubic yards	12.
	Clamshell - $\frac{3}{4}$ yard ²	1,000 cubic yards	17.
One way distance: 50 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	2.7
	- 5 yards	1,000 cubic yards	1.35
100 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	4.
	- 5 yards	1,000 cubic yards	2.
200 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	5.4
	- 5 yards	1,000 cubic yards	2.7
300 feet	Scoop loader - $2\frac{1}{2}$ yards	1,000 cubic yards	8.
	- 5 yards	1,000 cubic yards	4.
Trimming	Huber grader	1,000 cubic yards	6.7
Haul with trucks:	5-ton dump	1,000 cubic yards	42.
(Assume, approximately 4 round trips/hour)	20-ton dump	1,000 cubic yards	19.5
Spread spoil pile	D7F dozer	1,000 cubic yards	15.4
	D8K dozer	1,000 cubic yards	9.2
Spread excess earth	D7F dozer	1,000 cubic yards	28.6
	D8K dozer	1,000 cubic yards	17.2
Backfill	D7F dozer	1,000 cubic yards	18.2
	D8K dozer	1,000 cubic yards	11.
Compact 2 passes	Sheepsfoot (2 drums abreast)	1,000 square yards	.19
	Tamping foot	1,000 square yards	.1
4 passes	Sheepsfoot (2 drums abreast)	1,000 square yards	.39
	Tamping foot	1,000 square yards	.2
6 passes	Sheepsfoot (2 drums abreast)	1,000 square yards	.58
	Tamping foot	1,000 square yards	.29
Grading:	Huber grader	1,000 square yards	.1
(Digging side ditches, shaping crown, smoothing, etc.)			
4 round trips			
Hand work:³			Rates in man-hours
Excavate and load into trucks	Picks, shovels	cubic yard	3.
Spread loose soil	Shovels	cubic yard	.33
Backfill, shovel only	Shovels	cubic yard	1.33
Backfill and tamp	Shovels, pneumatic tamp	cubic yard	2.5
Haul up to 150 feet	Wheelbarrow	cubic yard	1.
Trim and fine grade	Shovels, rakes	100 square yard	2.
Shoring for basements, foundations, etc.			
Depth: 8-12 feet	Lumber, sheet piling	100 square feet	25.
14-20 feet	nails, hammers, saws	100 square feet	30.
8-12 feet	With pneumatic hammers	100 square feet	21.
14-20 feet	With pneumatic hammers	100 square feet	26.

¹Typical crew: 1 crew leader, 2 workers on excavation equipment, 2 to 6 workers on haul equipment, 1 worker on compact equipment, 1 worker on grading equipment.

²See table 6-8 for conversion factors for swing angle.

³Typical crew: 1 crew leader, 2 to 10 workers excavating, loading, spreading, backfilling, compacting, trimming, fine grading, tamping; 2 or more workers shoring.

TABLE 6-5
PREPARING SUBBASE AND BASE

Work element description	Equipment	Unit	Hours/Unit
Machine work:¹			Rates in machine-hours
Subbase:			
Scarify and shape	Scarify	D7F dozer with rippers	1,000 square yards 3.33
		D8K dozer with rippers	1,000 square yards 2.
	Shape	Huber grader	1,000 square yards 2.5
Compact	2 passes	Sheepsfoot (2 drums abreast)	1,000 square yards .19
		Tamping foot	1,000 square yards .1
	4 passes	Sheepsfoot (2 drums abreast)	1,000 square yards .39
		Tamping foot	1,000 square yards .2
	6 passes	Sheepsfoot (2 drums abreast)	1,000 square yards .58
		Tamping foot	1,000 square yards .29
	2 passes	9 tire pneumatic tire roller	1,000 square yards .25
	4 passes	9 tire pneumatic tire roller	1,000 square yards .49
	6 passes	9 tire pneumatic tire roller	1,000 square yards .74
	2 passes	2 axle, 5-8 ton tandem roller	1,000 square yards .29
	4 passes	2 axle, 5-8 ton tandem roller	1,000 square yards .58
	6 passes	2 axle, 5-8 ton tandem roller	1,000 square yards .89
	2 passes	50-ton pneumatic tire roller	1,000 square yards .29
	4 passes	50-ton pneumatic tire roller	1,000 square yards .58
	6 passes	50-ton pneumatic tire roller	1,000 square yards .89
Base course: Spread material		D7E dozer	1,000 cubic yards 3.33
		D8K dozer	1,000 cubic yards 2.
Shape surface		Huber grader	1,000 cubic yards 5.
		Huber grader	1,000 square yards 2.22
Compact gravel		Tandem roller, 8-ton	1,000 square yards 1.33
	10 passes	Rubber-tired roller	1,000 square yards 2.5
Hand work:²			Rates in man-hours
Spread, sprinkle and compact	Shovels, pneumatic tamps	cubic yard	2.
Fine grade, sprinkle, and compact	Rake, shovel, pneumatic tamp	square yard	.2

¹Typical crew: 1 crew leader, 2 to 4 workers on loading and shaping equipment, 2 to 6 workers on hauling equipment, 3 to 5 workers on spreading, sprinkling,

compacting, and fine-grading equipment.

²Crew: 1 crew leader, 2 to 10 workers spreading, sprinkling, compacting and fine grading.

TABLE 6-6
UNDERWATER EXCAVATION

Work element description	Equipment¹	Unit	Hours/Unit
Machine work:¹			Rates in machine-hours
Build dike around spoil area²			
Operate dredge	Hydraulic dredge	1,000 cubic yards	10.
Underwater excavation	Clamshell - ¾ yard	1,000 cubic yards	25.
	Dragline - ¾ yard	1,000 cubic yards	17.
Spoil disposal: (Truck: Assume 6 cubic yards/truck, 4 round trips/hours)	5-ton dump	1,000 cubic yards	42.
Spoil disposal: Barge	Barge with clamshell ³	1,000 cubic yards	50.
	Barge with dragline ³	1,000 cubic yards	33.3
			Rates in man-hours
Install and remove discharge lines (hand work)	Hydraulic dredge	100 linear feet	10.

¹Typical crew: 1 crew leader 4 to 7 workers installing and removing discharge lines, 3 to 5 workers per shift operating dredge (usually operated on a 2 or 3-shift basis around the clock), 1 worker with equipment building dike with 3 workers installing drainpipes through dike. For dragline or clamshell excavation, 1 operator and signal-person on dragline, 2 to 5 trucks with operators hauling

spoil, 1 worker to direct loading of spoil on barge, 2 barges (1 loading and 1 unloading), 2 workers and 1 bulldozer unloading barge at disposal area, 1 tugboat and crew (usually 3 to 5 workers).

²See earthmoving tables.

³Assume rotation of 2 barges per machine with short haul distance.

TABLE 6-7
CONVERSION FOR SOIL VARIABLES

Soil type	Type machine efficiency factors				Hand efficiency factors
	¾ yard power shovel	¾ yard dragline	¾ yard clamshell	2½ yard scoop loader	Manual
Loose sand-clay or moist loam	.82	.81	.74	.77	.65
Sand-gravel	.88	.84	.83	.83	.75
Good common earth	1.	1.	1.	1.	1.
Hard, tough clay	1.23	1.17	Not recommended	1.26	1.29
Rock, well blasted	1.43	Not recommended	Not recommended	Not recommended	Not recommended
Wet clay	1.93	1.91	Not recommended	Not recommended	Not recommended
Rock, poorly blasted	2.7	Not recommended	Not recommended	Not recommended	Not recommended

Note: Earthmoving tables compiled using "good common earth" as a norm. Therefore, to use this table, figure as follows:

$$\text{Hours required} = \frac{\text{quantity to be excavated}}{\text{unit}} \times \text{unit hours required} \times \text{efficiency factor}$$

TABLE 6-8
CONVERSION FOR SWING ANGLE AT OPTIMUM DEPTH

Equipment	Swing angle in degrees							
	30	45	60	75	90	120	150	180
Dragline	.76	.84	.9	.95	1.	1.1	1.21	1.3
Clamshell	.76	.84	.9	.95	1.	1.1	1.21	1.3
Power shovel	—	.8	.86	.93	1.	1.14	1.27	1.41

Notes:

1. Earthmoving tables compiled using 90° swing angle.
2. Table use: Rate of excavation to be used x swing angle-factor = new rate in hours.

TABLE 6-9
TYPICAL EARTH—VOLUME CONVERSION FACTORS

Soil type	Initial soil condition	Converted to:		
		In place	Loose	Compacted
Sand	In place	-	1.11	.95
	Loose	.9	-	.86
	Compacted	1.05	1.17	-
Loam	In place	-	1.25	.9
	Loose	.8	-	.72
	Compacted	1.11	1.39	-
Clay	In place	-	1.43	.9
	Loose	.7	-	.63
	Compacted	1.11	1.59	-
Rock (blasted)	In place	-	1.5	1.3
	Loose	.67	-	.87
	Compacted	.77	1.15	-

TABLE 6-10
MATERIAL WEIGHTS AND SWELL FACTORS

Material	Number per cubic yard (loose)	Number per cubic yard (in place)	Percent of swell	Swell factor
Cement, Portland	2,450	2,950	20	.83
Clay, natural red	2,700	3,500	30	.77
Clay and gravel, dry	2,300	3,100	34	.74
Clay and gravel, wet	2,600	3,500	34	.72
Concrete	2,650	3,700	40	.72
Concrete, wet mix	3,600	3,600	40	.72
Earth, loam, dry	2,300	2,850	25	.81
Earth, wet loam	2,750	3,400	24	.81
Granite	2,800	4,560	65	.6
Gravel, ¼ to 2 inches dry	2,850	3,200	12	.89
Gravel, ¼ to 2 inches wet	3,200	3,600	13	.89
Laterite	3,900	5,200	33	.75
Limestone, blasted	2,500	4,250	69	.59
Limestone, crushed	2,700	4,500	67	.6
Limestone, marble	2,700	4,550	69	.59
Mud, dry	2,100	2,550	21	.82
Mud, wet	2,650	3,200	21	.83
Sand, dry	2,750	3,100	13	.89
Sand, wet	3,150	3,600	14	.88
Sandstone, shot	2,700	4,250	58	.64
Shale, riprap	2,100	2,800	33	.75
Slate	3,600	4,700	30	.77
Coral, class #2, soft	1,760	2,900	65	.61
	2,030	3,350		
Coral, class #1, hard	2,030	2,900	67	.6
	2,440	4,075		

Notes:

1. Percent of swell times the bank (in place) cubic yards equals the loose cubic yards to be moved.
2. Swell factor times the loose cubic yards equals bank cubic yards being moved.
3. Compaction factor times the volume of the fill equals the loose material required for compacted fill.

TABLE 6-11
TRENCH EXCAVATION FACTORS

Trench depth (inches)	Trench width, inches						
	12	18	24	30	36	42	48
	Content of trench, cubic yards per 100 linear feet						
6	1.9	2.8	3.7	4.6	5.6	6.6	7.4
12	3.7	5.6	7.4	9.3	11.1	13.	14.8
18	5.6	8.3	11.1	13.9	16.7	19.4	22.3
24	7.4	11.1	14.8	18.5	22.2	26.	29.6
30	9.3	13.8	18.5	23.2	27.8	32.4	37.
36	11.1	16.6	22.2	27.8	33.3	38.9	44.5
42	13.	19.4	25.9	32.4	38.9	45.4	52.
48	14.8	22.2	29.6	37.	44.5	52.	59.2
54	16.7	25.	33.3	41.6	50.	58.4	66.7
60	18.6	27.8	37.	46.3	55.5	64.9	74.1

TABLE 6-12
GENERAL EXCAVATION FACTORS

Depth	Cubic yards to be removed per square foot of area
2 inches	.006
4 inches	.012
6 inches	.018
8 inches	.025
10 inches	.031
1 foot	.037
1½ feet	.056
2 feet	.074
2½ feet	.093
3 feet	.111
3½ feet	.13
4 feet	.148
4½ feet	.167
5 feet	.185
5½ feet	.204
6 feet	.222
6½ feet	.241
7 feet	.259
7½ feet	.278
8 feet	.296
8½ feet	.314
9 feet	.332
9½ feet	.35
10 feet	.369

Example:

Assume that an excavation is 24 feet x 30 feet and 6 feet deep. ($24 \times 30 = 720$). In the table, the 6 feet depth has a factor of 0.222 (the number of cubic yards in a excavation 1 foot square and 6 feet deep). Therefore, $720 \times 0.222 = 159.84$ cubic yards.

TABLE 6-13
FRONT END LOADER PRODUCTION

**Excavation from pit to truck pile
(hourly production)**

Bucket size	Haul distance			
	50'	100'	150'	200'
	Cubic yards			
1¼	39	28	21	17
2½	124	92	75	62
5½	312	244	200	167

Note: Figures are in loose cubic yards. Use table 6-1 to find the amount of bank cubic yards (in-place) removed per hour.

Example:

2½ cubic yards loader at 50' haul = 124 loose cubic yards.

124 cubic yards x swell factor for earth, loam, dry = 124 x .81 = 100 bank cubic yards in one hour.

TABLE 6-14
BULLDOZER PRODUCTION

**LOOSE CUBIC YARDAGE HOURLY PRODUCTION
BASE ON 50 MINUTE HOUR**

Dozer size	Haul distance					
	50'	100'	150'	200'	300'	400'
	Cubic yards					
Large (D-8/TD25)	435	285	210	170	125	95
Medium (D-7/TD20)	370	205	155	100	74	55
Small (D4/TD9)	105	65	46	34	22	—

Notes:

- Figures are in loose cubic yards. Use table 6-1 to find the amount of bank cubic yards (in place).
- Production is based on slot dozing. If work is done without slots, reduce figures by 25 percent.

Paving Operations

Chapter



TYPES

This chapter covers the construction of asphalt and concrete paving, curbs, and walks.

EQUIPMENT

The selection of equipment affects the number of workers required for paving operations. The use of transit-mixer trucks rather than paving mixers will usually increase the man-hours required to construct paving. Placing, spreading, and finishing equipment should be sized, whenever possible, to the plant equipment. If the paving equipment cannot handle the plant output, the plant will be idle part of the time waiting for the paving crew. If the plant output is less than the paving equipment can handle, the paving crew will be idle part of the time waiting for the plant. With some equipment, it is possible to cut the crew size and slow the paving operation to the plant capacity. However, this is not always possible and certainly is not efficient. The estimator should know what equipment will be used in order to take all factors into consideration.

ASPHALT

Construction of asphalt paving includes heating asphalt, marking pavement edges, brooming, priming, spreading and finishing asphaltic concrete, rolling asphaltic concrete, applying seal coat, applying tack coat, loading and hauling chips or gravel, spreading and rolling chips or gravel, and brooming chips or gravel. The time required to spread asphalt concrete with an asphalt finisher and to roll this material is important in only a few cases. Assuming normal operations, an asphalt finisher with the required rollers can spread and compact material faster than an asphalt plant can produce asphalt concrete. Therefore, in this chapter, only the plant output capacity will affect the paving time required for a given job.

CONCRETE

Construction of concrete paving includes placing forms, placing reinforcement, placing dowels, mixing concrete, placing concrete, finishing concrete, curing concrete, removing and cleaning forms, cutting or forming joints, pouring joint sealer and installing expansion joints.

CURBS AND WALKS

In the construction of curbs and walks, either concrete or asphaltic concrete may be used. This construction includes placing forms, expansion joints, reinforcement, concrete or asphaltic concrete. It also includes finishing and curing concrete, finishing asphaltic concrete, priming for asphaltic concrete, and rolling asphaltic concrete.

ESTIMATING TABLES

Use tables 7-1 through 7-3, on pages 7-3 through 7-5, to prepare man-hour estimates for paving, curbs, and walks. These tables do not include the delivery of materials to the jobsite.

EXAMPLES OF TABLE USE

Problem Number 1. Four miles of 2-inch thick asphaltic concrete (hot plant mix) 12 feet wide is to be placed on an existing road surface. The plant supporting this operation averages only 80 tons per hour. Assuming enough dump trucks to haul the plant mix, estimate the number of hours required for this paving operation.

Solution. Area to be paved = 4 miles x 12 feet x 5,280 feet/mile x 1 square yard/9 square feet = 28,160 square yards.

From table 7-2 we find that for a thickness of 2 inches and a plant output of 80 tons per hour under adverse conditions we require 13 hours/10,000 square yards.

Then, 28,160 square yards x 13 hours/10,000 square yards = 36.6 hours.

Thus, approximately 37 hours is required.

Problem Number 2. A prime coat of .3 gallon/square yard is to be applied to 3 miles of 18-foot wide roadway. An 800-gallon truck-mounted distributor with an 18-foot spray bar and 1/8-inch nozzle will be used. The average distance to the supply point is 12 miles, and it takes 20 minutes to refill the truck. Estimate the number of hours required for this operation.

Solution. From table 7-2 we find that at an application rate of .3 gallon/square yard the vehicle moves at a speed of 300 feet per minute and the truck empties in 5 minutes.

Thus, 300 feet per minute x 5 minutes = 1,500 linear feet/truck. 3 miles x 5,280 feet/mile = 15,840 feet/1,500 = 10½ (approximately 11 truckloads). This results in 55 minutes of actual spray time. However, travel time to and from the supply point and the time to fill the truck must also be calculated. Assuming an average speed to and from the supply point of 30 miles per hour,

Travel time = 12 miles/30 miles per hour x 2 (round trip) = 48 minutes

Load time given as 20 minutes

Unload time 5 minutes

Average cycle time = 73 minutes

Must make 11 trips x 73 minutes = 803 minutes/60 = 13.4 hours

TABLE 7-1
CONCRETE PAVING

Work element description	Equipment	Unit	Hours per unit
Formwork: place and remove		100 linear feet	5.5 man-hours
Reinforcing mesh and dowels		100 square feet	2. man-hours
Reinforcing steel and dowels		ton	35. man-hours
Mix and place	No. 34E paver	cubic yard	.02 man-hour
Place ready mix		cubic yard	.4 man-hour
Spread	Self-propelled concrete spreader with 2 Number 34E paver-mixers or 8 Number 16S mixers supporting	1,000 square yards	Gear: 1 - 1. machine hour 2 - .7 machine hour 3 - .6 machine hour 324 man-hours
Finish, by hand:		1,000 square yards	
Finish, by machine:	Transverse concrete finisher	1,000 square yards	Gear: 1 - 1. machine hour 2 - .8 machine hour 3 - .7 machine hour 4 - .5 machine hour
Place premolded expansion joint		1,000 linear feet	15 man-hours
Cut and form longitudinal and transverse joints	Concrete joint saws	1,000 linear feet	20 man-hours
Place joint sealer		1,000 linear feet	12 man-hours
Cure and clean up		1,000 square feet	15 man-hours

Crew workers 2 to 3 forming, 4 reinforcing, 6 to 8 mixing and placing, 6 finishing, 4 sawing and sealing joints.

TABLE 7-2
ASPHALT PAVING

This table differs from others because of the unusually short time required to empty an asphalt distributor tank. The application rate depends on the truck speed. The time required varies only with changes in bar lengths. To determine how much area is covered with one 800-gallon tankful, multiply the speed x spray bar length x time required to empty for the square foot area covered.

However, the most time-consuming part of this operation, which must be considered, is the travel time to and from the refueling point and the time required to refuel (up to ½ hour per tank).

For larger trucks (1,500-gallon) multiply the time required by 2.

Work element description	Equipment	Unit
Apply prime, tack, or seal coat (crew: operator)	800-gallon, truck mounted asphalt distributor	800 gallon
Spread and finish asphalt concrete	SA35 asphalt finisher ¹	10,000 square yards
Roll asphalt concrete (crew: operators)	9-14 ton, 3 wheel tandem 5-8 ton, 2 wheel tandem 10 ton, 3 wheel roller 9 tire pneumatic roller 50 ton pneumatic roller	10,000 square yards 10,000 square yards 10,000 square yards 10,000 square yards 10,000 square yards
Spread aggregate (crew: 3 workers)	Standard hopper type spreader	10,000 square yards
Sweep base prior to spraying	30 drawbar horsepower tractor sweeper	10,000 square yards
Mix-in-place and spread 2" bituminous mix (crew: operators)	CAT 12 grader	10,000 square yards

¹ Maximum recommended operating speed for an SA35 asphalt finisher is about 50 feet per minute. Therefore, 3.5 hours is the minimum time required for a finisher to cover 10,000 square yards. If paving thicknesses of ¾ inch or less, use 3.5 hours. (Average crew size = 6 workers on asphalt finisher.)

Note: For double-lane roads using one paver, additional time will be required if hot joint construction is desired.

Time required to empty in minutes

Rate of application gallon/square yard	Speed feet per minute	Spray bar length with ⅛" nozzle		
		12'	18'	24'
.1	900	7	5	3.5
.2	450	7	5	3.5
.3	300	7	5	3.5
.5	180	7	5	3.5
1.	90	7	5	3.5

Hours per unit asphalt plant output

Thickness	Adverse 80 tons per hour	Average 120 tons per hour	Favorable 150 tons per hour
1"	6.5	4.	3.5
2"	13.	8.	6.7
3"	19.	12.	10.

Hours required

3.2 machine hours
 3.4 machine hours
 3. machine hours
 3.1 machine hours
 3.5 machine hours

Width applied

4' 4.2 machine hours
 6' 3.3 machine hours
 8' 2.5 machine hours

4. machine hours

7.5 machine hours

TABLE 7-3
PAVING—CURBS AND WALKS

Work element description	Equipment	Unit	Hours per unit
Concrete curbs ¹:			
Formwork - Integral with paving		100 linear feet	10.5 man-hours
- Separate from paving		100 linear feet	22.5 man-hours
Combined curb and gutter		100 linear feet	25.5 man-hours
Place reinforcing		ton	35. man-hours
Mix and place concrete	16S Mixer	cubic yard	3.2 man-hours
Mix and place finish top	M919 concrete mobile	100 square feet	5.5 man-hours
Cure and clean up		1,000 square feet	1. man-hour
Concrete walks ²:			
Formwork		100 linear feet	4.5 man-hours
Mix and place (hand)		cubic yard	4.5 man-hours
Mix and place	16S Mixer	cubic yard	3. man-hours
Finish	M919 concrete mobile	100 square feet	5. man-hours
Place ready mix		cubic yard	1. man-hour
Cure and clean up		1,000 square feet	1. man-hour
Asphalt walks ³:			
Formwork		100 linear feet	4.5 man-hours
Prime coat		100 square feet	.7 man-hour
Spread asphalt	From 165-gallon asphalt kettle	100 square feet	2.9 man-hours
Roll asphalt	Probably nonstandard equipment - any tired vehicle	100 square feet	.6 man-hour

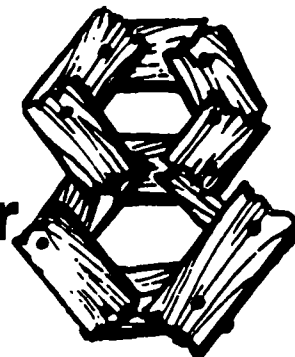
Crew workers:

¹ 3-4 forming, 2 reinforcing, 4 mixing and placing, 2 general labor

² 3 forming, 6-7 mixing and placing, 2-3 finishing and general labor

³ 3 forming, 3-4 manning kettle, 5 placing, 1 rolling

Chapter



Concrete Construction

TYPES

Concrete construction usually requires forming, reinforcing, mixing concrete, placing concrete, finishing concrete, stripping forms, and curing concrete. In addition, some concrete construction requires fine grading, vapor barriers, expansion joints, cold weather protection, and placement of embedded anchors in the concrete.

LABOR FOR FORMING

Labor required for forming includes fabrication, handling into place, erection, and oiling; installing form ties, tie wire, struts, chamfer strips, screed guides, bracing, and shoring; erecting runways and scaffolds; and checking forms during placement of concrete. Stripping includes removing, cleaning, and reconditioning forms. Forming is usually computed in square feet of contact surface, which is the area of concrete in direct contact with forms, or in linear feet of form required. Screed guides should be computed as the equivalent form length of an edge form.

LABOR FOR REINFORCED CONCRETE

Concrete is reinforced with steel bars, or with welded steel wire mesh which is used for reinforcing slabs, gunite, and precast concrete. In some applications, wire mesh and bars are used in combination for reinforcing. Some tables show both bars and mesh, so that the appropriate man-hours per unit may be used. Reinforcing steel is computed in tons of bars. Reinforcing mesh is computed in square feet of the area.

Labor for reinforcing steel includes handling into place, tying, supporting, and any cutting which becomes necessary at the site, such as cutting around embedded materials or cutting stock lengths of straight bars to fit slab dimensions. Labor for wire mesh reinforcing includes handling into place, cutting to fit, tying at overlaps, and pulling up into position during placement of concrete.

LABOR FOR MIXING CONCRETE

Sometimes concrete must be mixed at the jobsite rather than being delivered in transit-mix trucks. Labor for mixing concrete at the jobsite includes loading, measuring, wheeling, and dumping aggregates and cement into mixer; bringing water to the mixer by truck, hose, pipe, or pump; and operating the mixer.

LABOR FOR PLACING CONCRETE

Handling from the mixer or transit-mixer truck to final position is included in placing concrete. This includes hoisting, spreading, vibrating, and screeding the concrete to grade.

LABOR FOR FINISHING CONCRETE

Concrete finishing includes floating, troweling, and tooling slabs; and filling voids and honeycombs. Pointing and patching includes patching tie holes and removing fins.

LABOR FOR CURING CONCRETE

The term curing includes covering surfaces with curing compound, sand, paper, tarpaulins, burlap, or straw, and keeping wet as required.

FINE GRADING PROCESS

The process of fine grading includes bringing in fill or removing excess earth, spreading, leveling, compacting, and sprinkling when necessary.

VAPOR BARRIER PLACEMENT

Placing vapor barrier includes handling and placement, cutting to fit, smoothing as necessary, and sealing the joints.

EXPANSION JOINTS

Placing premolded expansion joints includes handling into place, cutting to fit, placing, and fastening to hold in position until concrete is placed. Labor for placing poured expansion joints includes cleaning joint of foreign matter, handling material to melting pot, melting, handling to joint, pouring joint, and dusting.

COLD WEATHER PROTECTION

Several methods are available to provide cold-weather protection for concrete. These include covering the concrete with sand, straw, or paper; heating the aggregates and mixing water; and building enclosures and operating heaters.

ESTIMATING TABLES

Work rates in tables 8-1 through 8-8, pages 8-3 through 8-6, are based on the use of untrained troops. If crews of different makeup are employed, the work rates must be adjusted accordingly. The tables do not include loading and hauling materials to the jobsite. Table 8-9, on page 8-7, contains conversion and waste factors.

TABLE 8-1
CONCRETE MIXING AND PLACING

Work element description	Unit	Men-hours/unit
Hand mix:		
1 Mix board ¹	cubic yard	2.5
16S Mixer:		
Charging with wheelbarrows		
Large crew ²	cubic yard	1.7
Small crew ³	cubic yard	2.
Placing: ⁴		
Placing directly into forms	cubic yard	.4
Using wheelbarrows	cubic yard	1.5
Using concrete buggies	cubic yard	1.25

¹ Crew: 9 to 10 workers.

² Crew: 14 workers: 1 operator, 7 with wheelbarrows loading gravel, 4 with wheelbarrows loading sand, 2 on cement.

³ Crew: 8 workers: 1 operator, 4 with wheelbarrows loading gravel, 2 with wheelbarrows loading sand, 1 on cement.

⁴ Crew: 9 workers: 1 leader, 6 wheeling concrete, 2 dumping and screeding.

TABLE 8-2
CONCRETE FOOTINGS AND FOUNDATIONS

Work element description	Unit	Men-hours/unit
Formwork:*		
Column footings	100 square feet	
(assume 5' x 5' x 1½')	of contact surface	8.5
Well footings	100 square feet	
(assume 1 foot deep)	of contact surface	5.5
Footing keys		
(assume 2" x 4")	100 linear feet	3.2
Reinforcing:		
Loose in footings and piers	ton	13.
Wired in place		
(vertical and horizontal)	ton	18.
Mesh or fabric reinforced	100 square feet	.5

*Crew: 2 carpenters, 1 helper.

**TABLE 8-3
CONCRETE SLABS ON GRADE**

Work element description	Unit	Man-hours/unit
Fine grade ¹	100 square feet	1.2
Formwork - edge form ²	100 linear feet	4.5
Screeds ¹	100 linear feet	1.25
Strip forms ≤ 12-inch ¹	100 linear feet	1.75
Reinforcing ¹		
Bend bars ≤ Number 8	1 ton	10.
Bend bars > Number 8	1 ton	5.
Place bars < Number 6	1 ton	15.
Place bars ≥ Number 6	1 ton	12.
Wire mesh	100 square feet	2.
Finish ¹		
Trowel (includes float)	100 square feet	2.5
Float	100 square feet	2.

¹ Crew: 1 worker.

² Crew: 2 carpenters, 1 helper.

**TABLE 8-4
CONCRETE STRUCTURAL SLABS**

Work element description	Unit	Man-hours/unit
Formwork:		
Flat slab including shoring ¹	100 square feet of contact surface	12.
Beam bottom, beam sides ¹	100 square feet of contact surface	17.5
Edge form ≤ 12 inches ¹	100 linear feet	7.
Strip forms ²	100 square feet	2.
Reinforcing ²		
Same as table 8-3 but hoisting of materials to slab level must be added.		
Finish:		
Same as table 8-3		
Carborundum stone rub underside	100 square feet	1.2
Placing:		
Rate of placing will depend on the method of hoisting the concrete.		

¹ Crew: 2 carpenters, 1 helper.

² Crew: 1 worker.

TABLE 8-5
CONCRETE WALLS

Work element description		Unit	Man-hours/unit
Formwork: ¹	Wall height (feet)		
Panel wall forms			
Making only	4 - 8	100 square feet	5.8
Erect and remove	3 - 4	100 square feet	5.
Erect and remove	5 - 8	100 square feet	9.
Foundation wall forms	4 - 8	100 square feet	10.5
Foundation wall forms	9 - 12	100 square feet	14.
Foundation wall forms	13 - 20	100 square feet	19.
Built in place forms	4 - 8	100 square feet	14.5
Built in place forms	9 - 12	100 square feet	19.
Built in place forms	13 - 20	100 square feet	24.
Reinforcing:			
Set bars		ton	24.7
Set bars and tie in place		ton	27.5
Cure and cleanup		1,000 square feet	1.
Finish (Carborundum stone)		100 square feet	2.8
Patch tie holes ²		100 square feet	1.2

¹ Crew: 2 carpenters, 1 helper.

² Crew: 1 finisher, 1 laborer.

TABLE 8-6
CONCRETE COLUMNS AND BEAMS

Work element description	Unit	Man-hours/unit
Formwork ¹		
Column forms	100 square feet	
(e.g. plywood sheathing)	of contact surface	20.5
Inside beam and girder forms	100 square feet	
with shoring	of contact surface	21.5
Spandrel beam or lintel forms	100 square feet	
with shoring	of contact surface	26.7
Reinforcing:		
Set bars	ton	26.5
Set bars and tie in place	ton	29.5
Finish (Carborundum stone)	100 square feet	2.8
Cure and cleanup	100 square feet	.1
Patch tie holes ²	100 square feet	1.2

¹ Crew: 2 carpenters, 1 helper.

² Crew: 1 finisher, 1 laborer.

TABLE 8-7
CAST-IN-PLACE CONCRETE CULVERTS

Work element description	Unit	Man-hours/unit
Formwork: ¹		
Plywood sheathing, etc.	100 square feet of contact surface	26.7
Place reinforcing:		
Set bars and tie in place	ton	31.5
Mix and place concrete ² (16S mixer)	cubic yard	2.7
Place ready-mix concrete ³	cubic yard	2.2
Finish	1,000 square feet	36.
Cure and cleanup	1,000 square feet	1.
Finish (Carborundum stone)	1,000 square feet	32.

¹ Crew: 2 carpenters, 1 helper.

² See table 8-1 for crew.

³ Typical crew: 1 crew leader, 4 workers erect/strip forms, 3 workers placing reinforcing, 6 to 8 workers placing, spreading, and vibrating concrete, 2 to 3 workers finishing, 1 to 2 workers cleanup.

TABLE 8-8
CAST-IN-PLACE CONCRETE AND INSTALL PRECAST CATCH BASINS

Work element description	Unit	Man-hours/unit
Cast-in-place units:		
Formwork ¹		
Plywood sheathing, etc.	100 square feet of contact surface	26.7
Reinforce:		
Set bars and tie in place	ton	31.5
Place manhole frame and cover	each	3.
Place catch basin grate	each	2.
Mix and place concrete ² (16S Mixer)	cubic yard	3.2
Place ready-mix concrete	cubic yard	2.7
Finish	100 square feet	3.6
Cure and cleanup	each	1.
Overall:		
For all sizes of all units	cubic yards	15.
Precast units:		
See table 6-5 for amount of labor per various sized units.		

¹ Crew: 2 carpenters, 1 helper.

² Mix crew: 5 workers on materials feeding mixer, 1 worker dumping concrete into buggies.

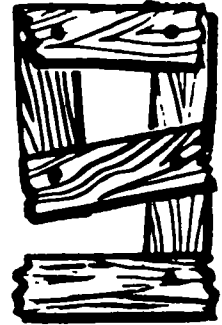
³ Placing crew: 1 crew leader, 3 to 5 workers setting and removing forms, 4 to 7 workers reinforcing, 3 to 5 workers placing concrete.

TABLE 8-9
CONVERSION AND WASTE FACTORS

Material	Conversion	Percent waste
CONCRETE CONSTRUCTION		
Concrete (1:2:4)		
Cement	6. sacks/cubic yerd	10
Fine eggrete	.5 cubic yard/cubic yerd	10
Coarse eggrete	.9 cubic yerd/cubic yard	10
Curing compound	.5 gallon/100 square feet	10
Forms		
Footings end piers		
2 x 4	1.5 linear foot/square foot of conctect surface	20
2 x 8	.2 linear foot/square foot of contact surface	10
2 x 12	.7 lineer foot/square foot of conctect surface	5
Wells end columns		
2 x 4	1.3 lineer foot/squere foot of conctect surface	20
Plywood (50% reuse)	.5 squere foot/squere foot of conctect surface	5
Beams and suspended slebs		
1 x 6	.3 lineer foot/square foot of conctect surface	5
2 x 4	.5 linear foot/squere foot of conctect surface	20
2 x 10	.1 linear foot/square foot of conctect surface	10
4 x 4	.4 linear foot/square foot of conctect surface	5
4 x 6	.1 linear foot/square foot of conctect surface	5
Plywood	.5 square foot/square foot of conctect surface	5
Form oil	.5 gellon/100 square foot	10
Tie wire	12. pounds/ton	10
Snap tie wedges	.1 eech/squere foot of conctect surface	5
Snep ties	.1 each/squere foot of conctect surface	5
She bolts	.1 set/square foot of conctect surface	5
Nails (board feet lumber, square foot plywood, ordered es thousand board foot meesure)		
6d box	6 pounds/thousand board foot measure	10
8d common	4 pounds/thousand board foot meesure	10
16d common	6 pounds/thousand board foot measure	10
20d common	2 pounds/thousand board foot meesure	10
6d duplex	4 pounds/thousand board foot measure	10
8d duplex	9 pounds/thousand board foot measure	10
16d duplex	9 pounds/thousand board foot measure	10

Chapter

Carpentry



TYPES

This chapter covers rough carpentry work and installation of flooring, finish carpentry, windows, doors, and insulation.

ROUGH CARPENTRY

The term rough carpentry includes measuring, cutting, and installing wood framing, floor joists and sills, cross bridging, wall framing and plates, roof framing and rafters, and rough door bucks. The installation of wall and roof sheathing and siding is also included in rough carpentry.

FLOORS

This includes measuring, cutting, and installing subflooring, finish flooring, and soft tile (asphalt, cork, rubber, and vinyl). It also covers installing building paper under finish floors and adhesive under tile floors. In addition, flooring includes installing building paper under soft tile laid over wood floors.

FINISH CARPENTRY

The work of finish carpentry includes installing baseboard, molding, door and window frames, trim, kitchen cabinets, wooden stairs, closet units, and finish walls. Finish carpentry also includes installation of fastening devices such as plugs, expansion shields and toggle bolts; blocking for leveling and plumbing; and scribing fillers and trim to walls and adjacent pieces.

WINDOWS AND DOORS

The tables in this chapter cover the installation of double-hung and casement windows, jalousies, skylights, wood doors of all types, louvers, screens, and venetian blinds, as well as caulking and weather-stripping. Installation includes drilling for fasteners, installing plugs, expansion shields, toggle bolts, blocking, hinges, locks, and other hardware.

INSULATION

The installation of insulation includes scaffolding when required, fastening insulation into place, and making cutouts in insulation as required.

ESTIMATING TABLES

Tables 9-1 through 9-9, on pages 9-4 through 9-8, may be used to prepare detailed man-hour estimates for carpentry. Tables do not include provision for loading and hauling materials to the job. All tables assume average working conditions in terms of weather, skill, motivation, crew size, accessibility, and the availability of equipment. Tables 9-10 and 9-11, on pages 9-8 and 9-9, contain conversion factors.

EXAMPLE OF TABLE USE

Problem. A 24-foot by 40-foot frame storage shed is to be built as a part of a training program. Its interior partitions will be covered on both sides with plasterboard. Ceiling joists will be covered with plasterboard. Exterior walls will be covered with 4 foot by 8 foot treated fiberboard and 1 inch by 8 foot shiplap siding. There will be four interior doors, four exterior doors, and eight double-hung windows, all with plain trim.

The estimates show the following quantities:

Floor joists and sills	1,300 board feet
Wall framing and plates	2,120 board feet
Ceiling joists	785 board feet
Cross bridging	288 pair
Roof framing and rafters	2,089 board feet
Sheathing 4 foot by 8 foot fiberboard	1,280 square feet
Roof sheathing 1 inch by 8 foot	1,410 square feet
Siding 1 inch by 8 foot shiplap	1,280 square feet
Subflooring 4 foot by 8 foot plywood	960 square feet
Finish flooring softwood	960 square feet
Door frame and trim	8 each
Window frame and trim	8 each
Finish walls - plasterboard	2,240 square feet
Windows - double hung	8 each
Doors - single interior	4 each
Doors - single exterior	4 each

Determine the man-hours needed for this project.

Solution. Using tables 9-1 through 9-11, the following computations are made:

Floor joists and sills, 1.300 thousand board feet measure x 32 man-hours	= 41.6
Wall framing and plates, 2.120 thousand board feet measure x 56 man-hours	= 118.7
Ceiling joists, .785 thousand board feet measure x 32 man-hours	= 25.1
Cross bridging, 2.88 hundred pair x 5 man-hours	= 14.4
Roof framing and rafters, 2.089 thousand board feet measure x 48 man-hours	= 100.3
Sheathing 4 foot x 8 foot fiberboard, 1.280 thousand square feet x 24 man-hours	= 30.7
Roof sheathing 1 inch by 8 feet, 1.280 thousand square feet x 24 man-hours	= 33.8
Siding 1 inch by 8 feet, 1.280 thousand square feet x 48 man-hours	= 61.4
Subflooring 4 foot by 8 foot plywood, .96 thousand square feet x 16 man-hours	= 15.4
Finish flooring softwood, .960 thousand square feet B x 24 man-hours	= 23.0
Door frame and trim, 8 x 2.5 man-hours	= 20.0
Window frame and trim, 8 x 3 man-hours	= 24.0
Finish walls - plasterboard, 2.240 thousand square feet x 48 man-hours	= 107.5
Windows - double hung, 8 x 2.5 man-hours	= 20.0
Doors - single interior, 4 x 1.5 man-hours	= 6.0
Doors - single exterior, 4 x 2 man-hours	= <u>8.0</u>
Total man-hours required	+ 649.9
Use 650 man-hours	

TABLE 9-1
ROUGH FRAMING

Work element description	Unit	Man-hours/unit
Beams (3-2" x 8')	Thousand board foot measure	30
Floor joists, sills	Thousand board foot measure	25
Bridging	100 pairs	5
Wall frames, plates	Thousand board foot measure	45
Furring, include plugging	1,000 linear feet	32
Blocking	Thousand board foot measure	20
Grounds for plaster	1,000 linear feet	48
Door bucks	Each	3
Ceiling joists	Thousand board foot measure	25
Rafters	Thousand board foot measure	45

		Man-hours assembly	Man-hours placement
Trusses	Each		
Span feet			
20		1.5	1
30		2.	8
40		12.	8
50		20.	6*
60		24.	6*
80		32.	6*

Typical crew: 1 leader, 8 workers. Minimal crew: 1 leader, 2 workers

*Assumes use of organizational crane, 1 operator, 1 oiler, 2 or 3 workers on guylines.

TABLE 9-2
SHEATHING AND SIDING

Work element description	Unit	Man-hours/unit
Wall sheathing	1,000 square feet	
Building paper		8
Tongue and groove		24
Plywood		16
Fiberboard		16
Roof decking	1,000 square feet	
Tongue and groove		32
Plywood		20
Siding	1,000 square feet	
Plywood		16
Corrugated asbestos		32
Drop siding		32
Narrow bevel		48
Shingles		40

Typical crew: 1 leader, 8 workers.

TABLE 9-3
INSULATION

Work element description	Unit	Man-hours/unit
Thermal	1,000 square feet	
Board		
Floor*		32
Wall		8
Ceiling		24
Roof		24
Rock wool		
Loose		16
Batts		12
Foil alone		8
Rigid foam		24
Acoustic	1,000 square feet	
Strip		24
Quilt		8

Typical crew: 1 leader, 4 workers.

*Install vermin shield.

TABLE 9-4
FINISH CARPENTRY

Work element description	Unit	Man-hours/unit
Walls	1,000 square feet	
Plywood		32.
Plasterboard (includes tape)		48.
Ceilings	1,000 square feet	
Wood		48.
Plasterboard (includes tape*)		64.
Cemented tile		32.
Panel with suspension		72.
Baseboard (2 member)	1,000 linear feet	72.
Molding (chair)	1,000 linear feet	48.
Door frame, trim	each	2.5
Sliding door with pocket	each	8.
Window frame, trim	each	3.
Installing prefab closets	each	16.
Setting kitchen cabinets	each	1.5
Shelving	1,000 square feet	64.
Chalkboard (complete)	1,000 square feet	110.
Stairs		
Closed stringer, built on job	story	16.
Closed stringer, prefab	story	8.
Open stringer	story	24.

Note: Typical crew: 1 leader, 3 to 8 workers.

For small rooms increase time required for wall and ceiling board installation by 30 to 50 percent.

*Includes of furring strips when necessary.

TABLE 9-5
DOOR INSTALLATION

Work element description	Unit	Man-hours per unit
WOOD DOORS AND FRAMES		
Door frames and trim		
Single exterior	each	3
Double exterior	each	3
Single interior	each	3
Double interior	each	4
Sliding door frame	each	4
Door: fit, hang and lock		
Single exterior	each	5
Double exterior	each	8
Single interior	each	5
Double interior	each	7
Screen doors	each	2
METAL DOORS		
Single	each	6
Double	each	9
MISCELLANEOUS DOORS COMPLETE WITH TRIM AND HARDWARE		
Rolling, manual operated	each	29
Rolling, motor operated	each	36
Sliding, manual operated	each	20
Sliding, motor operated	each	25
Sliding, fire	each	19
Garage doors		
Wood 16' x 7'	each	8
Aluminum 16' x 7'	each	10
Scuttles	each	10
CAULKING	1,000 linear feet	5

Notes:

1. Includes jambs, stops, casings and weather stripping.
2. Does not include sills or thresholds.
3. On wood doors, if power planes, hinge butt routers and lock mortisers are used; deduct 25 percent from installation time.

TABLE 9-6
FLOORING

Work element description	Unit	Man-hours/unit
Wood floors	1,000 square feet	
Subfloors		
Tongue and groove		24
Plywood		16
Finish floor		
Softwood		24
Hardwood		32
Soft tile	1,000 square feet	
Cemented		24
Nailed		32
Linoleum	1,000 square feet	32

Typical flooring crew: 1 leader, 4 workers.

TABLE 9-7
WINDOW INSTALLATION

Work element description	Unit	Man-hours/unit
Wood windows		
Double hung	each	4
Casement, single	each	4
Fixed wood sash	each	3
Jalousie	each	2
Skylights	each	8
Louvers	each	5
Screens	each	2
Venetian blinds	each	2
Metal windows		
Double hung	each	2
Casement	each	2
Commerical projected	each	2
Skylights	each	9
Weatherstripping	each	3
Caulking	1,000 linear feet	

Notes:

1. Suggested crew size: Two to six workers.
2. Installation includes drilling fasteners, expansion sills, installing plugs, toggle blocking, hinges, locks, and other hardware.
3. For special panic device doors, add three hours for single, four hours for double doors.

TABLE 9-8
INTERIOR PAINTING

Work element description	Unit	Man-hours per unit
Brush painting, per coat		
Wood flat work	1,000 square feet	11
Doors and windows, area	1,000 square feet	12
Trim	1,000 square feet	9
Plaster, sand finish	1,000 square feet	10
Plaster, smooth finish	1,000 square feet	10
Plasterboard	1,000 square feet	8
Metal	1,000 square feet	12
Masonry	1,000 square feet	12
Varnish flat work	1,000 square feet	9
Enamel flat work	1,000 square feet	7
Enamel trim	1,000 square feet	13
Roller painting, per coat		
Wood flat work	1,000 square feet	7
Doors	1,000 square feet	9
Plaster, sand finish	1,000 square feet	4
Plaster, smooth finish	1,000 square feet	5
Plasterboard	1,000 square feet	5
Metal	1,000 square feet	7
Masonry	1,000 square feet	5
Spray painting, per coat		
Wood flat work	1,000 square feet	4
Plaster, plasterboard	1,000 square feet	4
Metal	1,000 square feet	5
Masonry	1,000 square feet	4
Taping flushing, joints, sanding, plasterboard	1,000 linear feet of joint	54
Sanding wood floors	1,000 square feet	12
finish wood floors, sealer and 1 finish coat	1,000 square feet	21

Note: The painting of interior surfaces includes surface preparation, mixing paint materials, and application of paint to surface.

TABLE 9-9
EXTERIOR PAINTING

Work element description	Unit	Man-hours per unit
Brush painting, per coat		
Wood siding	1,000 square feet	12
Wood doors and windows	1,000 square feet	12
Area of opening		
Trim	1,000 linear feet	11
Steel sash, area of opening	1,000 square feet	9
Flat metal	1,000 square feet	12
Metal roofing and siding	1,000 square feet	10
Masonry	1,000 square feet	12
Roller painting, per coat		
Masonry	1,000 square feet	10
Flat metal	1,000 square feet	9
Doors	1,000 square feet	9
Spray painting, per coat		
Wood siding	1,000 square feet	5
Doors	1,000 square feet	9
Masonry	1,000 square feet	8
Flat metal	1,000 square feet	7
Metal roofing and siding	1,000 square feet	8
Airfield lines and numbers, Including glass beads	1,000 square feet	14
Cementitious paint, including curing	1,000 square feet	16
Sandblasting steel	1,000 square feet	66
Wirebrush cleaning of steel	1,000 square feet	38
Clean and spray waterproofing on masonry	1,000 square feet	14

Notes:**1. Suggested crew size:**

One to five workers spraying, 1 to 5 workers tending (one worker is used to mix and prepare paint for larger crews.). Sandblasting crew a minimum of four.

2. Surface preparation for exterior painting includes removing mill scale from metal surfaces with wire brushes or by sandblasting, removing dust with brush or cloth, removing oil and grease, masking and taping adjacent surfaces, removing masking and taping. Sometimes it is necessary to lightly sand between coats, or size and fill porous materials before painting, all of which is surface preparation.

3. Labor for erecting scaffolding not included.

TABLE 9-10
NUMBER OF STUDS FOR PARTITION, FLOOR JOIST, AND CEILING JOIST

Distance on center	Multiply length of partition by	Add
12 inches	1.	1
16 inches	.75	1
24 inches	.5	1

Note: Add for top and bottom plates on stud walls.

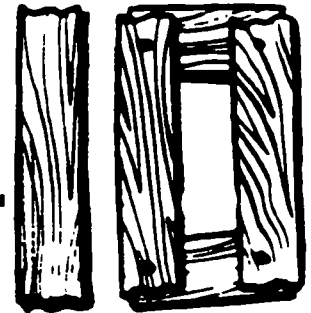
TABLE 9-11
NUMBER OF WOOD JOISTS REQUIRED FOR FLOOR AND SPACING

Length of span (feet)	Spacing of joists (inches)		
	12	16	24
6	7	6	4
7	8	6	5
8	9	7	5
9	10	8	6
10	11	9	6
11	12	9	7
12	13	10	7
13	14	11	8
14	15	12	8
15	16	12	9
16	17	13	9
17	18	14	10
18	19	15	10
19	20	15	11
20	21	16	11
21	22	17	12
22	23	18	12
23	24	18	13
24	25	19	13
25	26	20	14
26	27	21	14
27	28	21	15
28	29	22	15
29	30	23	16
30	31	24	16
31	32	24	17
32	33	25	17
33	34	26	18
34	35	27	18
35	36	27	19
40	41	31	21

R

Masonry

Chapter



TYPES

Masonry covers installing brick, concrete block, mortar-bound rubble, ceramic tile, quarry tile, structural tile (glazed or face), and also lathing and plastering.

BRICK AND CONCRETE BLOCK

Labor for the installation of brick and concrete block includes mixing mortar, carrying materials to the mason, hoisting materials, and laying brick and block. It also includes tooling joints, erecting and dismantling scaffold, sawing block, culling brick and block. Labor for this type of masonry includes cleaning brick and block in place.

MORTAR-BOUND RUBBLE

The installation of mortar-bound rubble includes labor for mixing mortar, rough-cutting stone, carrying mortar and rubble to the mason, hoisting materials, and laying rubble. Tooling and pointing joints, erecting and dismantling scaffold, and cleaning rubble in place are also part of the installation.

CERAMIC AND QUARRY TILE

The installation of ceramic and quarry tile includes mixing mortar for bed coat and joints, carrying mortar and tile to the tilesetter, spreading bed coat, cutting tile, and setting tile. Labor estimates should also include slushing and finishing joints, cleaning tile in place, and erecting and dismantling scaffold.

STRUCTURAL TILE

The installation of structural face tile and glazed structural tile units includes mixing mortar, carrying mortar and tile to the mason, hoisting materials, laying tile, tooling joints, erecting and dismantling scaffold, cutting tile, and cleaning tile in place.

LATH AND PLASTER

Labor for lathing and plastering includes handling material into place; hoisting materials; cutting and installing hanging wires and straps; cutting and fastening lathing channels, angles, beads, and moldings; installing furring strips, metal lath, and gypsum lath. Labor also includes mixing plaster; installing and finishing plaster; erecting and dismantling scaffold; and curing and drying plaster.

ESTIMATING TABLES

Unit masonry tables 10-1 through 10-3, on pages 10-3 through 10-4, include mixing mortar, carrying materials, culling, cutting, hoisting, laying masonry, tooling joints, and cleaning work in place. For lathing (table 10-4, on page 10-4), labor includes installing required metal fastenings and furring. Estimates for plastering (table 10-5, on page 10-5) include mixing, hoisting, finishing, and curing. Allowances are made for erecting and dismantling scaffolds in all cases. Estimates do not provide for loading and hauling material to the job site. Tables 10-6 and 10-7, on pages 10-5 and 10-6, contain conversion factors.

EXAMPLE OF TABLE USE

Problem. Twenty housing units are to be built in Germany when weather is generally favorable to construction. Estimate the number of working days it will take to complete the project. Material estimates are as follows:

8-inch concrete block	20,000 square feet
Acid cleaning block	20,000 square feet
6-inch quarry tile	1,000 square feet
Tile base (6-inch)	500 linear feet
Acid cleaning tile	1,250 square feet
Glass block	1,000 square feet
Metal lath - walls (metal studs)	25,000 square feet
Metal lath - ceiling (wood joists)	10,000 square feet
Metal lath - base	2,500 linear feet
Corner bead	2,500 linear feet
Lath at openings	4,000 linear feet
Plastering walls (2 coats)	25,000 square feet
Plastering walls (plain finish)	10,000 square feet
Scaffolding	1 story - 8 crews

Solution. Labor is mostly inexperienced, so man-hours/unit is figured at 30 percent above tables:

	Unit	x	Man-hours/unit =	Subtotal
Laying block	20.		143	2,860
Cleaning block	20.		33	660
Laying tile:				
Floor	1.		208	208
Base	0.5		299	150
Cleaning tile	1.25		13	16
Glass block	1.		325	325
Metal lath:				
Walls	25.		52	1,300
Ceiling	10.		13	130
Base	2.5		46	115
Corner	2.5		46	115
Openings	4.		91	364
Plastering:				
Walls	25.		31	775
Ceilings	10.		55	550
Scaffold	8.		26	208
Total man-hours				7,776

Assuming an 8-hour workday, work requires 972 man-days. An engineer company consisting of 60 laborers, using organic equipment, could complete the project in 16.2 ($972 \div 60$) working days.

TABLE 10-1

~~BRICK, CONCRETE BLOCK, AND MORTAR-BOUND RUBBLE~~

See ch. 1.
Structural Tile

Work element description	Unit	Man-hours/unit
Backup tile	1,000 square feet	
4" wall		100
8" wall		100
12" wall		140
Glazed tile	1,000 square feet	
4" wall		230
8" wall		280
Glass and terra cotta block, complete	1,000 square feet	200
Acid cleaning tile	1,000 square feet	10

Typical tile crew: 1 leader, 6 workers

See Ch 1

~~TABLE 10-2~~ **BRICK, CONCRETE BLOCK, AND MORTAR-BOUND RUBBLE**
~~STRUCTURAL TILE~~

Work element description	Unit	Man-hours/unit
Common brick	1,000 square feet	
8" wall		150
12" wall		200
16" wall		300
Acid cleaning brick	1,000 square feet	20
Concrete block	1,000 square feet	
4" wall		76
8" wall		100
12" wall		150
Acid cleaning block	1,000 square feet	25
Mortar-bound rubble, complete	cubic yard	30
Erect and dismantle tubular scaffold	story-1 crew	20

Typical crew: 1 leader, 6 workers for masonry; 1 leader, 3 workers for scaffolding.

TABLE 10-3
CERAMIC AND QUARRY TILE

Work element description	Unit	Man-hours/unit
Floors	1,000 square feet	
Ceramic		
Paper-backed		160
Unmounted		240
Quarry		
4-inch square		200
6-inch square		160
9-inch square		80
Walls (includes preparation of surface)	1,000 square feet	250
Base	1,000 linear feet	230
Cap	1,000 linear feet	190

Typical tile crew: 1 leader, 3 workers.

TABLE 10-4
LATHING

Work element description	Unit	Man-hours/unit
Walls	1,000 square feet	
Wood lath		10
Metal lath		10
Wood studs, 2-inch solid partition		35
Metal studs, 2 sides		25
Ceiling	1,000 square feet	
Wood joists		10
Suspended		30
Base	1,000 linear feet	
Wood		30
Metal		35
Corner bead	1,000 linear feet	35
Moldings at openings	1,000 linear feet	70

Typical lathing crew: 1 leader, 3 workers.

TABLE 10-5
PLASTERING

Work element description	Unit	Man-hours/unit
Interior walls	1,000 square feet	
2 coats		21
3 coats		21
2" solid partition		70
Metal studs, 2 sides		40
Ceiling (3 coats)	1,000 square feet	42*
Exterior, stucco	1,000 square feet	45

Typical plastering crew: 1 leader, 6 workers.

*Add 8 man-hours/unit for sand finish.

TABLE 10-6
MASONRY CONVERSION UNITS

Material description	Conversion unit	Waste %	Unit
Masonry units			
8 inch blocks	.89 square foot per block		
1. Full stretcher	8" x 8" x 16"	10 each	each
2. Half stretcher	8" x 8" x 8"	10 each	each
3. Corner block	8" x 8" x 16"	10 each	each
4. Full jamb	8" x 8" x 16"	10 each	each
5. Half jamb	8" x 8" x 8"	10 each	each
6 inch blocks	.89 square foot per block		
1. Full stretcher	6" x 8" x 16"	10 each	each
2. Half stretcher	6" x 8" x 8"	10 each	each
3. Corner	6" x 8" x 16"	10 each	each
4. Full jamb	6" x 8" x 16"	10 each	each
5. Half jamb	6" x 8" x 8"	10 each	each
Note: All specials requiring field cutting shall be ordered as full size blocks.			
Mortar materials. (For 1 to 3 mix and 8" x 16" blocks)			
Cement, Portland, Type I (includes 20% waste)			
1. ¼ inch joint	.80 cubic feet/100 square foot wall	—	sacks
2. ⅜ inch joint	1.10 cubic feet/100 square foot wall	—	sacks
3. ½ inch joint	1.40 cubic feet/100 square foot wall	—	sacks
Lime, Hydrated, Dry Type "M" (includes 20% waste)			
Note: 1 sack lime = 1 cubic foot			
1. ¼ inch joint	.60 cubic feet/100 square foot wall	—	sack
2. ⅜ inch joint	.81 cubic feet/100 square foot wall	—	sack
3. ½ inch joint	1.05 cubic feet/100 square foot wall	—	sack
Masonry wash materials.			
Muratic acid	10 pounds/100 square foot surface	10 pound	pound
Soap, powdered, navy type	2 pounds/100 square foot surface	10 pound	pound
Core fill materials. (Conversion units for RST spaced (24" OC)			
Cement, Portland, Type I			
1. 8 and 6 inch walls	3 sacks/100 square foot wall	10 sack	sack
2. 4 inch walls	2 sacks/100 square foot wall	10 sack	sack

Notes:

1. Volume of 1 cell in an 8- by 8-inch block is equal to ⅓ cubic foot.
2. 7 sacks/cubic yard.

TABLE 10-7
MATERIAL WEIGHTS AND MEASURES

Material	Length inches	Width inches	Thickness inches	Weight pounds/ each	Weight pounds/ barrel	Weight pounds/ cubic foot	Weight pounds/ cubic yard	Weight tons/ 1,000
Asbestos						110 to 120		
Brick, common	8¼	4	2½	5.4				2.7
Brick, fire, std.	9	4½	2½	7.				3.5
Brick, hard	8½	4¼	2¼	6.48				3.24
Brick, soft	8¼	4	2¼	4.32				2.6
Cement, bag				94.	376			
Clay, dry						63 to 95	1,700 to 2,295	
Clay, fire						130	3,500	
Clay, wet						120 to 140	2,970 to 3,200	

Roofing

Chapter



TYPES

The types of roofing included in this chapter are built-up, roll, shingle, metal, asbestos-cement, and tile. Table 11-1, on page 11-2, includes melting asphalt, laying felt, mopping, and laying gravel for built-up roofing. Table 11-2, on page 11-2, includes cleaning deck, applying prime coat, and laying rolls for roll roofing. Table 11-3, on page 11-2, includes placing and nailing shingle roofing. Table 11-4, on page 11-3, includes placing, caulking, drilling, and fastening materials for metal, asbestos-cement, and tile roofing.

ESTIMATING TABLES

Tables 11-1 through 11-5, on pages 11-2, through 11-3, may be used in preparing detailed man-hour estimates for roofing. These tables include allowances for unloading and storing materials at the construction site, and hoisting. They do not include hours needed for loading and hauling materials to the jobsite.

EXAMPLE OF TABLE USE

Problem. A warehouse is to be built in a tropical area. Heavy rains require a 4-ply built-up roof to be applied during the dry season. Estimate the number of man-hours needed to build the roof, based on the following material estimate:

Roof, 4-ply built-up	5,000 square feet
Roof insulation	5,000 square feet
Flashing	300 linear feet

Solution. Because crews are inexperienced, man-hours/unit is increased 30 percent over figures given in table 11-1.

	Unit	x	Man-hours/unit =	Subtotal
Roof, 4-ply built-up	5		33	165
Insulation	5		33	165
Flashing	0.3		78	23
Total man-hours				353

TABLE 11-1
BUILT-UP ROOFING, INSULATION, AND FLASHING

Work element description	Unit	Man-hours/unit
Roofing	1,000 square feet	
2 ply		12
3 ply		20
4 ply		25
5 ply		30
Insulation	1,000 square feet	25
Flashing	1,000 linear feet	60

Typical crew: 1 leader, 6 workers.

TABLE 11-2
ROLL ROOFING

Work element description	Unit	Man-hours/unit
Paper (plain) and felt	1,000 square feet	7
Asphaltic aluminum (including primer)	1,000 square feet	18
Canvas (including 2 coats paint)	1,000 square feet	25

Typical crew: 1 leader, 6 workers.

TABLE 11-3
SHINGLE ROOFING

Work element description	Unit	Man-hours/unit
Wood	1,000 square feet	35
Slate	1,000 square feet	55
Metal	1,000 square feet	50
Asphalt	1,000 square feet	30

Typical crew: 1 leader, 4 workers.

TABLE 11-4
METAL, ASBESTOS-CEMENT, AND TILE ROOFING
 (pitch at least 3 inches/foot)

Work element description	Unit	Man-hours/unit
Metal	1,000 square feet	
Corrugated and V-crimp		
Wood purlins		18
Metal purlins		36
Sheet (seamed)		60
Asbestos-cement	1,000 square feet	
Wood purlins		35
Metal purlins		45
Tile	1,000 square feet	
Clay		55
Metal		60

Typical crew: 1 leader, 5 workers.

TABLE 11-5
WATERPROOFING

Work element description	Unit	Man-hours/unit
Built-up roofing		
3 ply	square	4.
4 ply	square	5.
5 ply	square	6.
Roof insulation	square	
Asphaltic aluminum roofing		
Asphaltic primer	square	1.5
Asphaltic aluminum	square	1.5
Shingle roofing (including felt paper)		
Asphalt shingles	square	5.
Wood shingles	square	7.
Asbestos shingles	square	9.
Corrugated roofing		
Corrugated or V-crimp metal		
On wood purlins	square	3.5
On metal framing	square	7.
Corrugated asbestos, cement		
On wood purlins	square	6.
On metal framing	square	8.

Suggested crew size: 4 to 12 workers.

Notes:

1. All estimates are based on 50 percent experienced crews with good supervision.
2. Insulation installation should not exceed that which can be covered with roofing the same day.
3. For below grade waterproofing use 75 percent of figures listed.
4. Crew size will be dictated by safety, equipment used, scope of work and the number of operations involved.

Electrical Work

Chapter



TYPES

Electrical work discussed in this chapter includes construction of electrical distribution lines, outdoor lighting, and underground power systems. It also includes installation of interior electrical services, transformers, and substation equipment.

ELECTRICAL LINE WORK

Labor includes unloading materials, excavating, installing crossarms and insulators, setting poles, backfilling, stringing and sagging wire. It also includes installing and connecting transformers, switches, breakers, capacitors, and regulators.

OUTDOOR LIGHTING

Street lights, security lights, airfield lights, and athletic field lights are types of outdoor lighting. Labor for installation includes digging foundations, setting poles, backfilling, installing standards and light fixtures, stringing wire, laying buried cable, installing duct, encasing duct in concrete, and pulling cable. It also includes installing control devices, lamps, control vaults, and transformers.

UNDERGROUND POWER SYSTEM

This includes excavating, installing ducts, encasing ducts with concrete, backfilling, and compacting. It also includes pulling cable, constructing transformer vaults, installing transformers, and constructing manholes and handholds. Time of construction depends on soil and weather conditions.

INTERIOR ELECTRICAL ROUGH-IN

This includes installing service mains, switches, panels, conduits, fittings, outlet boxes, nonmetallic cable, armored cable, transformers, and motor control centers. Rough-in also includes pulling cable through conduit and splicing in electrical boxes.

INTERIOR ELECTRICAL FINISH AND TRIM

This includes installing and connecting receptacles, switches, light fixtures, light duty devices, heavy duty utility devices, controls, and appliances. It also includes circuit testing.

TRANSFORMERS AND SUBSTATION EQUIPMENT

Installation of transformers and substation equipment includes unloading the equipment, moving it into position, leveling, plumbing, fastening, trimming, and connecting.

ESTIMATING TABLES

Tables 12-1 through 12-9, on pages 12-4 through 12-9, may be used in preparing detailed man-hour estimates for electrical construction. The tables do not include provisions for loading and hauling equipment and materials to the jobsite. Man-hours units are given in these tables for average working conditions. To apply these tables to a particular situation, the weather condition, skill and experience of the workers, time allotted for completion, size of crew, types of material used, and types of equipment must be considered.

EXAMPLE OF TABLE USE

To make an estimate of man-hours for electrical work using the tables in this chapter, follow the procedure in the example below.

Problem. Interior electrical work is to be performed in a two-family housing unit. The work element estimate shows the following quantities of work to be performed:

Electrical service main, 100 amperes	1 each
Electric panels, 8-circuit	2 each
Conduit and boxes, 1-¼ inches and smaller	1,100 linear feet
Pull and splice wire, Number 10 and smaller	2,200 linear feet
Pull and splice wire, Number 8 and larger	160 linear feet
Receptacles and switches	30 each
Incandescent fixtures	14 each
Attic exhaust fans	2 each
Hot water heater	2 each

Solution. Because the project is located in an area of moderate rainfall and most of the crew are experienced workers, subtract 15 percent from the man-hour estimates. Referring to tables 12-5, 12-6, and 12-7 compute at 85 percent the man-hours per unit as follows:

Electric service main, 100 amperes 12.0 (.85)	= 10.25 each
Electric panels, 8-circuit 9.0 (.85)	= 7.65 each
Conduit and boxes, 1-¼ inches and smaller 250.0 (.85)	= 212.50/1,000 linear feet
Pull and splice wire, Number 10 and smaller 18.0 (.85)	= 15.30/1,000 linear feet
Pull and splice wire, Number 8 and larger 56.0 (.85)	= 47.5/1,000 linear feet
Receptacles and switches 0.2 (.85)	= 0.17 each
Incandescent fixtures 0.5 (.85)	= 0.43 each
Attic exhaust fans 2.0 (.85)	= 1.70 each
Hot water heater 1.5 (.85)	= 1.28 each
Using the above units, compute man-hours for electrical work.	

Rough-in:

Service main: 1 each x 10.20 man-hours each	= 10.2
Panels: 2 each x 7.65 man-hours each	= 15.3
Conduit: 1.1 x 1,000 linear feet x 212.5 man-hours/1,000 linear feet	= 233.8
Wire, Number 10: 2.2 x 1,000 linear feet x 15.3 man-hours/1,000 linear feet	= 33.7
Wire, Number 8: .16 x 1,000 linear feet x 47.5 man-hours/1,000 linear feet	= <u>7.6</u>
Total man-hours for rough-in	= 300.6

Finish and Trim:

Receptacles and switches: 30 each x .17 man-hours/each	= 5.1
Fixtures: 14 each x .43 man-hours/each	= 6.0
Fans: 2 each x 1.7 man-hours/each	= 3.4
Hot water heater: 2 each x 1.28 man-hours/each	= <u>2.6</u>
Total man-hours for finish and trim	= 17.1
Total electrical work in one two-family housing unit: 300.6 + 17.1	= 318 man-hours

TABLE 12-1
ELECTRICAL LINE WORK

Work element description	Unit	Man-hours/unit
Set poles, including guying, hardware and grounding:		
Line poles	each	3.
Corner poles	each	4.
H-pole and transformer platform	each	9.
String wire including connections:		
Number 6 to Number 1 wire	1,000 linear feet	40.
Number 1/0 to Number 4/0 wire	1,000 linear feet	96.
Set pole-mounted transformers:		
50 kilovolt-amperes	each	2.
25 to 37.5 kilovolt-amperes 10	each	2.
5 to 15 kilovolt-amperes 10	each	2.
Pole top air break switches	each	2.
Disconnect switches	each	2.
Guying and tying	1,000 linear feet	100.
Capacitors:		
Single phase (10)	each	1.2
Three phase (30)	each	3.
Regulators:		
12.5 to 25 kilovolt-amperes 10 pole-mounted	each	15.
12.5 to 37.5 kilovolt-amperes 30 platform mounted	each	30.
50 to 75 kilovolt-amperes 30 platform mounted	each	50.
100 to 125 kilovolt-amperes 30 platform mounted	each	70.
For quick estimates:		
Line work complete	1,000 linear feet	200.

Typical crew: 1 crew leader, 4 line persons, 2 splicers, 2 ground persons, 1 truckdriver, and 1 crane operator.

Equipment: Compressor, pneumatic air-tamper, crane, truck, tractor with a winch drum and cable, stringing blocks and slings, bolt cutters, grips, chains, cable, and rope.

Not included in these estimates are man-hours required for hole-digging.

TABLE 12-2
STREET, SECURITY, AND ATHLETIC FIELD LIGHTING

Work element description	Unit	Man-hours/unit
Install foundations for light standards:		
Street lighting	each	19.2
Security lighting	each	19.2
Athletic field lighting	not applicable	not applicable
Install lighting standards including wiring:		
Street lighting	each	16.
Security lighting	each	16.
Athletic field lighting	not applicable	not applicable
Setting poles:		
Street lighting	each	24.8
Security lighting	each	24.8
Athletic field lighting	each	32.
Trench excavation for burial cable:		
Hand	1,000 linear feet	640.
Machine	1,000 linear feet	40.
Install fixtures, including wiring	each	12.
Install direct burial cable including risers and splicing when applicable	1,000 linear feet	48.
Install overhead cable, including splicing	1,000 linear feet	40.
Install lighting transformer		
10 to 20 kilovolt-amperes	each	16.
25 to 30 kilovolt-amperes	each	24.
Install control devices	each	8.
Install lamps	each	.64
For quick estimates:		
Street lighting, complete	1,000 linear feet	256.
Security lighting, complete	1,000 linear feet	360.
Athletic field lighting, complete	luminaire	5.2

Typical crew: 1 crew leader, 2 workers excavating, 4 workers setting poles and installing fixtures, 1 truckdriver, and 1 crane operator.

Equipment: Crane, truck, compressor, pneumatic air-tamper, and ordinary handtools.

TABLE 12-3
AIRFIELD LIGHTING

Work element description	Unit	Man-hours/unit
Install burial cable, including splicing	1,000 linear feet	48.
Trenching for ducts or cable, including backfill and compaction:		
Hand	cubic yard	8.8
Machine	1,000 cubic yard	560.
Install duct	1,000 linear feet	272.
Incase duct in concrete	cubic yard	3.2
Pull cable, including splicing	1,000 linear feet	64.
Install lighting fixtures including wiring	each	12.
Install control devices	each	8.
Install control vaults	each	192.
For quick estimates:		
Airfield lighting complete using machine excavation:		
Direct burial cable	1,000 linear feet	216.
Duct system (2-way)	1,000 linear feet	976.

Typical crew: 1 crew leader, 2 workers trenching, 3 workers placing concrete, 5 workers pulling and splicing cable, 2 workers installing fixtures and control devices, and 1 truckdriver
 Equipment: Ditcher, air compressor with tamper, backhoe, truck soldering outfits, fishing wire, and handlines.

TABLE 12-4
UNDERGROUND POWER SYSTEM

Work element description	Unit	Man-hours/unit
Trenching for ducts, including backfill and compaction:		
Machine	1,000 cubic yards	560.
Hand	cubic yards	8.8
Install ducts, including risers	1,000 linear feet	288.
Incase ducts with concrete	cubic yards	3.2
Pull cable, including splicing	1,000 linear feet	112.
Install transformers:		
100 kilovolt-amperes dry type	each	80.
167 kilovolt-amperes to 500 kilovolt-amperes dry type	each	136.
Transformer vaults	each	See table 8-8
Manholes and/or handholes	each	See table 8-8
For quick estimates: ducts complete, including machine excavation, backfill, and concrete incasement:		
2-way ducts	1,000 linear feet	792.
4-way ducts	1,000 linear feet	1,496.
6-way ducts	1,000 linear feet	2,208.
9-way ducts	1,000 linear feet	3,248.
Underground power system, complete *	1,000 linear feet	2,400.

Typical crew: 1 crew leader, 2 workers excavating, 3 workers placing concrete, 5 workers pulling and splicing, 1 truckdriver, and 4 to 8 workers on transformer installation.

* Includes complete duct installation, pulling and splicing cable, manholes, handholes, transformer vaults, and transformers.

TABLE 12-5
ELECTRICAL ROUGH-IN—HOUSING AND BARRACKS

Work element description	Unit	Man-hours/unit
Electric service main:		
30 amperes service	each	5
60 amperes service	each	7
100 amperes service	each	9
Electric panels:		
8 circuit	each	8
16 circuit	each	15
Install conduits, fittings, and outlet boxes:		
1 ¼ inches and smaller	1,000 linear feet	250
1 ½ inches and larger	1,000 linear feet	420
Pull and splice wire:		
Number 10 and smaller	1,000 linear feet	18
Number 8 and larger	1,000 linear feet	56
Install nonmetallic cable, fittings, and outlet boxes:		
Number 10 and smaller	1,000 linear feet	28
Number 8 and larger	1,000 linear feet	48
Install armored cable, fittings, and outlet boxes:		
Number 10 and smaller	1,000 linear feet	55
Number 8 and larger	1,000 linear feet	66

Typical crew: 1 crew leader, 3 workers on conduit installation, and 4 workers on wire pulling and splicing.

Equipment: Heavy rigid conduit work will require pipe cutters, hacksaws, threading tools, reamers, and other small tools needed for conduit work. Light rigid conduit work will not require threading tools. Other small tools needed will include hand and electric drills, saws, hammers, chisels, gasoline torches, soldering outfits, fishing wire, pliers, and handlines. Ladders, stepladders, sawhorses, and planks may be needed for scaffolding.

Notes:

1. A predominance of small size conduit will create a more favorable condition than a big percentage of large size conduit in either conduit item.
2. A large number of short length circuits would tend to create unfavorable conditions and would increase the man-hours required to pull and splice each 1,000 linear feet of cable. Similarly a predominance of very short conduit runs would increase the number of man-hours required per 1,000 linear feet.

TABLE 12-6
ELECTRICAL FINISH AND TRIM—HOUSING AND BARRACKS

Work element description	Unit	Man-hours/unit
Install receptacle and switches	each	.2
Install incandescent fixtures	each	.5
Install fluorescent fixtures	each	1.
Install appliances: *		
Dryers, hot water heater, ranges	each	1.5
Small space heaters	each	1.
Air conditioning units 1 ton and smaller	each	3.
Exhaust fans	each	2.
Circuit testing	circuit	.5

Typical crew: 1 crew leader and 2 to 4 workers.

Equipment: Ordinary handtools and ladder if needed.

* Based on standard size appliances.

TABLE 12-7
ELECTRICAL ROUGH-IN—INDUSTRIAL

Work element description	Unit	Man-hours/unit
Electric service main:		
60 amperes service 340 W	each	11.2
100 amperes service 340 W	each	12.
200 amperes service 340 W	each	14.
Electric panels:		
8 circuit	each	9.
16 circuit	each	16.
24 circuit	each	19.
30 circuit	each	21.
Install conduit, fittings and outlet boxes		
1 1/4 inches and smaller	1,000 linear feet	250.
1 1/2 inches and larger	1,000 linear feet	420.
Install cable, including splicing:		
No. 10 and smaller	1,000 linear feet	28.
No. 8 and larger	1,000 linear feet	48.
Install nonmetallic cable, fittings, and outlet boxes:		
No. 10 and smaller	1,000 linear feet	55.
No. 8 and larger	1,000 linear feet	66.
Install metallic cable fittings and outlet boxes:		
No. 10 and smaller	1,000 linear feet	64.
No. 8 and larger	1,000 linear feet	96.
Transformers, floor-mounted ¹ :		
1 to 3 kilovolt-amperes	each	8.
5 to 10 kilovolt-amperes	each	17.6
15 to 25 kilovolt-amperes	each	38.4
37.5 to 50 kilovolt-amperes	each	76.8
Motor control centers (average section 24" x 96" x 14") ²	per section	23.2

Typical crew: 1 crew leader, 2 to 3 workers on panels, 3 to 5 workers on conduit, 3 to 5 workers on stringing cable and splicing, and 2 to 4 workers on transformer installation.

Equipment: Heavy rigid conduit work will require pipe cutters, hacksaws, threading tools, and so forth. Light rigid conduit work will not require threading tools. See table 12-5.

¹ Three-Phase four-wire wye system

² Add 20 percent for wall or column mounting.

TABLE 12-8
ELECTRICAL FINISH AND TRIM—INDUSTRIAL

Work element description	Unit	Man-hours/unit
Install receptacles and switches	each	.3
Install incandescent light fixtures	each	.6
Install fluorescent light fixtures	each	2.
Hook up light duty devices including testing	each	3.
Hook up heavy duty devices including testing, with controls	each	12.
Circuit testing	circuit	.5

Typical crew: 1 crew leader and 2 to 3 workers.

Equipment: Ordinary handtools and ladder or scaffold if needed.

TABLE 12-9
BURGLAR AND FIRE ALARM SYSTEMS

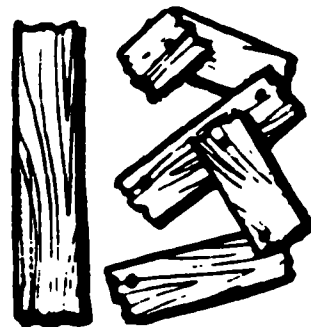
Work element description	Unit	Man-hours/unit
Burglar alarm:		
Open and closed circuit springs	each	.8
Contactors	each	1.8
Electric matting	each	1.8
Constant ringing drop	each	2.9
Relays	each	2.3
Fire alarm:		
Auto thermostat	each	1.6
Special outlet box	each	1.1
Bell	each	1.3
Horn or small motor-driven siren	each	2.1
Annunciator mounting	each	2.2
Annunciator connections	per terminal	.4
Control panel	each	7.2
Transformers	each	7.2
Cable pulled in conduit	1,000 linear feet	11.2
Cable exposed	1,000 linear feet	19.2

Typical crew: 1 crew leader and 1 to 3 workers.

Equipment: Ordinary handtools.

Plumbing

Chapter



TYPES

Plumbing consists of installing cast iron and steel pipe, valves and fittings, fire hydrants, thrust blocks, concrete pipe, vitrified clay pipe, asbestos-cement pipe; roughing in plumbing; and installing fixtures.

PIPE

The installation of cast iron and steel pipe includes unloading, placing, joint make-up, and testing. The installation of concrete and vitrified clay pipe includes unloading, placing, caulking, grouting, installing gaskets, and testing. The installation of concrete and vitrified clay pipe includes unloading, placing, caulking, grouting, installing gaskets, and testing. The installation of asbestos-cement pipe includes unloading, placing, installing gaskets, soaping, pulling sleeve over joint, and testing.

VALVES AND FITTINGS

The installation of valves and fittings includes unloading, placing, caulking and leading, welding, and bolting flanges. It also includes installing gaskets, packing, handwheels, and trim.

FIRE HYDRANTS, POST INDICATOR VALVES, AND THRUST BLOCKS

The installation of fire hydrants and post indicator valves includes unloading, placing, caulking, bolting, clamping, adjusting to grade, and plumbing stems. The installation of thrust blocks includes bracing, forming, reinforcing, placing concrete, and stripping forms.

ROUGH-IN PLUMBING

The rough-in of plumbing includes unloading and installing sewer and drain pipe, installing water pipe, and testing. The installation of cast iron drains includes caulking and leading joints, plumbing and grading pipe, installing pipe hangers and straps, cutting pipe, and installing fittings. The installation of galvanized steel pipe vents and drains includes cutting and threading pipe, making joints and applying joint compound, plumbing and grading pipe, installing pipe hangers and straps, and installing fittings. The installation of copper and galvanized steel water pipe includes cutting, threading and making steel pipe joints, cleaning and soldering copper pipe joints, plumbing and grading pipe, and installing pipe hangers and straps.

FINISH PLUMBING

The installation of finish plumbing includes setting and connecting all plumbing fixtures (such as bathtubs, lavatories, water closets, urinals, showers, and sinks).

ESTIMATING TABLES

Tables 13-1 through 13-7, on pages 13-3 through 13-8, may be used in preparing detailed man-hour estimates for plumbing installations. The tables do not include provision for loading and hauling equipment and materials to the jobsite. The installation of polyvinyl chloride pipe includes cleaning, applying solvent, drying time and installation of hangers and supports. Table 13-8, on page 13-8, gives information on needed quantities of solvent.

EXAMPLE OF TABLE USE

Problem. Twenty housing units are to be constructed. Estimate the number of man-hours needed for rough-in. Activity estimates show the following quantities:

Rough-in sanitary lines 4 inch cast iron and smaller	145 joints
Rough-in water lines $\frac{3}{4}$ inch and smaller threaded pipe	185 joints
Rough-in fixtures:	
Bathtub with shower	20 each
Lavatory	20 each
Water closet	20 each
Kitchen sink	20 each

Solution. Using tables 13-1 through 13-8, the following computations are made:

4 inch and smaller cast iron drain line		
145 joints x .85 man-hours	=	123
¾ inch and smaller water line		
185 joints x .5 man-hours	=	92
Rough-in fixtures:		
Bathtub with shower 20 each x 4 man-hours	=	80
Lavatory 20 each x 3 man-hours	=	60
Water closet 20 each x 3 man-hours	=	60
Kitchen sink 20 each x 3 man-hours	=	60
Total man-hours for rough-in	=	475
Use 570 man-hours		

TABLE 13-1
INSTALLATION OF PIPE—WELDED STEEL PIPE LINES

Work element description	Unit	Man-hours/unit
Install schedule 40 pipe, by oxyacetylene welding, butt weld; positions include horizontal, vertical, and overhead		
1 inch	joint	.6
1¼ inches	joint	1.02
1½ inches	joint	1.12
2 inches	joint	1.15
2½ inches	joint	1.43
3 inches	joint	1.67
3½ inches	joint	1.87
4 inches	joint	2.13
5 inches	joint	2.74
6 inches	joint	3.73
8 inches	joint	4.91
10 inches	joint	6.72
Install schedule 40 pipe, by metallic arc welding, butt welds; positions include horizontal, vertical, and overhead		
1 inch	joint	.5
1¼ inches	joint	.5
1½ inches	joint	.5
2 inches	joint	.5
2½ inches	joint	.5
3 inches	joint	.5
3½ inches	joint	.75
4 inches	joint	.75
5 inches	joint	.75
6 inches	joint	.85
8 inches	joint	.85
10 inches	joint	1.

The time for installation of the pipe includes erecting and aligning pipe in hangers, cutting and beveling one end of pipe, and welding pipe.

Schedule 40 steel pipe corresponds to former designation: "standard". Schedule 80 steel pipe corresponds to former designation: "extra strong". Schedule number is selected using formula: Schedule Number = $1000 \times P/S$, where P is operating pressure, psig and S is allowable stress value, psi. For schedule 80 pipe multiply man-hours by 1.6.

This table is based upon a crew of 3 workers: 1 pipefitter, 1 welder, and 1 helper.

TABLE 13-2
INSTALLATION OF THRUST BLOCKS, VALVES, AND FITTINGS—WELDED STEEL PIPE LINES

Work element description	Unit	Man-hours/unit
Install thrust-blocks for (2 worker crew)		
12-inch and smaller pipe	each	6.4
14- to 24-inch pipe	each	9.6
Install ¹ standard (welded) fittings, butt welded, oxyacetylene and arc, all positions		
1 inch	each	.45
1 ¼ inches	each	.65
1 ½ inches	each	.7
2 inches	each	.88
2 ½ inches	each	1.14
3 inches	each	1.36
3 ½ inches	each	1.48
4 inches	each	1.62
5 inches	each	2.06
6 inches	each	2.64
8 inches	each	3.56
10 inches	each	5.11
Install ² standard valves, oxyacetylene and metallic arc		
1 inch	each	.5
1 ¼ inches	each	.95
1 ½ inches	each	1.05
2 inches	each	1.15
2 ½ inches	each	1.38
3 inches	each	1.62
3 ½ inches	each	1.86
4 inches	each	2.06
5 inches	each	2.62
6 inches	each	3.58
8 inches	each	5.06
10 inches	each	7.08

¹ This is based on the average time required to erect, align, and weld-up fittings. The crew consists of two workers: 1 welder and 1 helper.

For extra-heavy fittings multiply by a factor of 1.3.

² This is based on the average time it takes for a crew of 2 workers (welder and helper) to erect and align, and weld-out the fittings on the valve.

For extra-heavy fittings, multiply by a factor of 1.5.

TABLE 13-3
INSTALLATION OF STEEL PIPE—THREADED AND FLANGED (SCHEDULE 40)

Work element description	Unit	Man-hours/unit
Install threaded and flanged valves (schedule 40)		
2 inches	each	.6
2 ½ inches	each	.72
3 inches	each	.82
3 ½ inches	each	1.
4 inches	each	1.1
5 inches	each	1.4
6 inches	each	1.9
8 inches	each	2.
10 inches	each	2.5
12 inches	each	3.

TABLE 13-3 (CONTINUED)
INSTALLATION OF STEEL PIPE—THREADED AND FLANGED (SCHEDULE 40)

Work element description	Unit	Man-hours/unit
Install threaded pipe, schedule 40		
½ - ¾ inch	joint	.5
1 inch	joint	.5
1 ¼ inches	joint	.5
1 ½ inches	joint	.5
2 inches	joint	.5
2 ½ inches	joint	.75
3 inches	joint	.75
3 ½ inches	joint	.75
4 inches	joint	.75
5 inches	joint	1.
6 inches	joint	1.
8 inches	joint	1.5
Install schedule 40 pipe, flange fittings		
2 inches	joint	.25
2 ½ inches	joint	.25
3 inches	joint	.25
3 ½ inches	joint	.35
4 inches	joint	.35
5 inches	joint	.35
6 inches	joint	.5
8 inches	joint	.5
10 inches	joint	.65
12 inches	joint	.75
Install thrust block		
12 inches and smaller	each	6.4
14 inches and larger	each	9.6
Install flanged fittings (schedule 40)		
2 inches	each	.8
2 ½ inches	each	.88
3 inches	each	.96
3 ½ inches	each	1.06
4 inches	each	1.6
5 inches	each	1.94
6 inches	each	2.2
8 inches	each	2.68
10 inches	each	2.72
12 inches	each	5.8

This table is based on the fabrication and installation of pipe per joint. The job operations taken into account are making fittings service tight, installing, handling materials and tools, and threading one end per joint.

Crew size in table is based on 1 pipefitter and 1 helper for pipe under 4 inches. For 4 inches and over 1 pipefitter and 2 helpers are used.

For extra-heavy (schedule 80) pipe and screwed fittings multiply by a factor of 2.

For schedule 120 pipe and screwed fittings multiply by a factor of 3.

The time required to test a piping system is generally based on a percentage of the total amount of labor-hours the job requires. The most accurate percentage to use is 6.

TABLE 13-4
INSTALLATION OF VITRIFIED CLAY PIPE

Work element description	Unit	Man-hours/unit
Install vitrified clay pipe and fittings		
4 to 6 inches	joint ¹	.25
8 inches	joint ²	.3
10 inches	joint	.5
12 inches	joint	.6
15 inches	joint	.95
18 inches	joint	1.1
21 inches	joint	1.25
24 inches	joint	1.4
30 inches	joint	1.75
36 inches	joint	2.

¹ Joint size is 2 feet 6 inches.

² Joint size is 3 feet for all remaining pipe.

This table is based on a crew of 6 workers for all pipe up to and including 21 inches. For larger pipe a crane and operator are needed, thus increasing the crew size to 7.

TABLE 13-5
FINISH PLUMBING

Work element description	Unit	Man-hours/unit
Install fixture including all trim		
Lavatory	each	3
Water closet	each	4
Slop sink	each	4
Residential hot water heater	each	3
Garbage disposal	each	3
Urinal	each	3
Bathtub	each	5
Urinal with stall	each	4
Footbath	each	4
Kitchen sink	each	5
Shower with stall	each	8
Bathtub with shower	each	7

This table is based on a crew of 2 workers: 1 plumber and 1 helper.

TABLE 13-6
ROUGH-IN PLUMBING

Work element description	Unit	Men-hours/unit
Install sewer pipe		
4 to 12 inches	feet	.45
Install cast iron drain lines and fittings		
4 inches	joint ¹	.85
6 inches	joint	1.
8 inches	joint	1.3
Pipe work (steel) threaded pipe (schedule 40)		
½ to ¾ inch	joint	.5
1 inch	joint	.5
1¼ inches	joint	.5
1½ inches	joint	.5
2 inches	joint	.5
2½ inches	joint	.75
3 inches	joint	.75
3½ inches	joint	1.
4 inches	joint	1.
Copper tubing ²		
¾ to ½ inch	joint	.25
¾ inch	joint	.5
1 to 1¼ inches	joint	.5
Roughing work		
Levatory	each	3.
Water closet	each	3.
Shower with stall	each	8.
Stop sink	each	3.
Urinal with stall	each	3.
Bathtub	each	3.
Kitchen sink	each	3.
Bathtub with shower	each	4.
Floor drain	each	1.
Grease trap	each	2.
Valves, faucets, etc., installed with rough plumbing		
1 inch or less	each	.5
1 to 2 inches	each	.5
2 inches and over	each	.75
Test plumbing system, per fixture		1.

¹ A joint is the connection that joins pipe with pipe, pipe with a valve, pipe with a coupling, and so forth.

² Usually less than half as many joints will be required for copper tubing than for steel pipe of equal length.

This table is based on a crew of 2 workers: 1 plumber and 1 helper.

TABLE 13-7
INSTALL POLYVINYL CHLORIDE PIPE, SOLVENT WELDED

Work element description	Unit	Man-hours/unit
½ inch pipe	1,000 linear feet	2.9
¾ inch pipe	1,000 linear feet	5.5
1 inch pipe	1,000 linear feet	8.
1¼ inch pipe	1,000 linear feet	11.
1½ inch pipe	1,000 linear feet	13.5
2 inch pipe	1,000 linear feet	13.5
3 inch pipe	1,000 linear feet	13.5
4 inch pipe	1,000 linear feet	20.
Fittings:		
Time is based on per 10 fittings		
Couplings:		
½ inch	per 10	.3
1 inch	per 10	.5
2 inch	per 10	.9
3 inch	per 10	1.5
Elbows:		
½ inch	per 10	.3
1 inch	per 10	.5
2 inch	per 10	1.
3 inch	per 10	1.5
4 inch	per 10	2.5
Tees:		
½ inch	per 10	.4
1 inch	per 10	.6
2 inch	per 10	1.5
3 inch	per 10	2.
4 inch	per 10	2.5

Suggested crew size: 2 to 4 workers

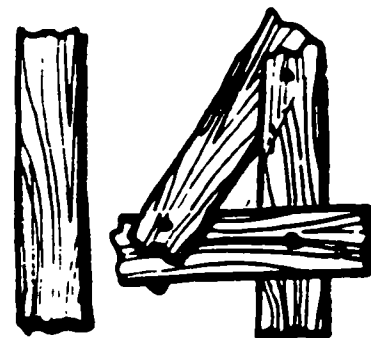
Note: Polyvinyl chloride solvent will not work with "C" polyvinyl chloride. Each must have a special solvent cement.

TABLE 13-8
POLYVINYL CHLORIDE SOLVENT REQUIREMENTS

Size fittings	Number of joints	Pint	Number of tees	Number of joints	Quart	Number of tees
		Number of couplings or elbows			Number of couplings or elbows	
½"	350	175	115	700	350	230
¾"	200	100	65	400	200	130
1"	150	75	50	300	150	100
1¼"	110	55	35	220	110	70
1½"	80	40	25	160	80	50
2"	45	22	15	90	45	30
3"	35	17	12	70	35	25
4"	25	12	8	50	25	15
6"	16	8	5	32	16	10
8"	10	5	3	20	10	6

Equipment Installation

Chapter



TYPES

Installation of equipment includes unloading, moving into location, uncrating, cleaning, assembling, positioning, aligning, supporting, and anchoring if required.

UNLOADING WORK

The work of unloading and moving in includes lifting or skidding from the truck; transporting with equipment, or rolling or skidding into approximate position. The typical crew for this work is one crew leader and two to five workers depending on the weight and size of the equipment. Mechanical lifting equipment is normally used to unload and move the heavier pieces.

CLEANING AND ASSEMBLING WORK

The work of cleaning and assembling includes uncrating, removing protective paper and coating, removing grease and oils, removing rust, assembling and attaching any parts shipped loose, removing shipping oils, flushing oil reservoirs and filling with the proper lubricant. The typical crew for this work is one crew leader and one to four workers.

POSITIONING AND ALIGNING WORK

The work of positioning and aligning includes moving into position, bringing to grade, leveling, aligning, and connecting drives. The typical crew for this work is one crew leader and two to four workers.

SUPPORTING AND ANCHORING WORK

The work of supporting and anchoring includes installing shims and plates, grouting, drilling for expansion shields, installing expansion shields, drilling and tapping baseplates, installing bolts, and installing washers and nuts. The typical crew for this work is one crew leader and two to four workers.

CONNECTING EQUIPMENT

The work of connecting equipment includes initial wiring, piping, or duct connection. It does not include installing breakers, switches, controls, dampers, or valves. The typical crew for this work is one crew leader and one to four workers.

ESTIMATING TABLES

Tables 14-1 through 14-8, on pages 14-2 through 14-6, may be used in preparing detailed man-hour estimates for equipment installation. The tables do not include provision for loading and hauling equipment to jobsite or for piping, wiring, or ductwork other than the initial connection to the equipment.

TABLE 14-1
INSTALLATION OF AIR COMPRESSORS AND PUMPS

Work element description	Unit	Man-hours/unit	Crew size
Electric driven compressor tank unit:			
5 to 20 cubic feet per minute	1	10	2
25 to 50 cubic feet per minute	1	12	2
Motor and compressor set (reservoir tank not included):			
75 to 250 cubic feet per minute	1	16	2 - 3
275 to 500 cubic feet per minute	1	30	3 - 4 ¹
550 to 750 cubic feet per minute	1	50	4 - 6 ¹
Motor and pump set (reservoir tank not included):			
50 to 200 gallons per minute	1	12	2
250 to 750 gallons per minute	1	20	2 - 3 ¹
800 to 1,250 gallons per minute	1	30	3 - 5 ¹

¹ Need forklift truck when working inside a building.

Add 20 percent to man-hours if fuel-burning engines are used. Compressor pressures are 100 - 250 pounds per square inch.

TABLE 14-2
INSTALLATION OF AIR CONDITIONING EQUIPMENT

Work element description	Unit	Man-hours/unit	Crew size
Window air-conditioning units:			
½ to ¾ ton	1	5	1 - 2
1 to 1½ ton	1	7	1 - 2
2 to 2½ ton	1	9	1 - 2
Self-contained, water cooled air-conditioning units:			
3 to 5 ton	1	42	2 - 4
5 to 8 ton	1	55	2 - 4
10 to 15 ton	1	80	3 - 5
Central air-conditioning equipment			
3 to 5 ton	1	40	3 - 4
5 to 8 ton	1	70	3 - 5
10 to 15 ton	1	90	4 - 6
15 to 25 ton	1	200	4 - 6
25 to 50 ton	1	300	4 - 6
50 to 75 ton	1	600	5 - 10
75 to 100 ton	1	1,000	5 - 12

Note: Installation does not include piping and wiring to and between equipment.

TABLE 14-3
INSTALLATION OF ELECTRIC MOTORS AND EXHAUST FANS

Work element description	Unit	Man-hours/unit	Crew size
Electric motors with switches:			
1 to 5 horsepower	1	3	1
5 to 15 horsepower	1	5	1 - 2
15 to 30 horsepower	1	16	2 - 3 ¹
30 to 100 horsepower	1	48	2 - 3 ¹
Exhaust fans:			
12 to 24 inches	1	2	1
26 to 42 inches	1	6	1 - 2
48 to 60 inches	1	6	2 - 3 ¹
Louvers for exhaust fans:			
12 to 24 inches	1	10	1 - 2
26 to 42 inches	1	16	2 - 3 ²
48 to 60 inches	1	20	2 - 3 ²
Power ventilators:			
6 to 20 inches	1	8	1 - 2
24 to 42 inches	1	21	2 - 3

¹ Needs forklift truck to move if working inside a building. Same truck or hoist is used to position and align.

² May need scaffolding if high on wall.

Man-hours for louvers include fabricating and setting at site.

TABLE 14-4
INSTALLATION OF HEATING BOILERS AND EXPANSION TANKS

Work element description	Unit	Man-hours/unit	Crew size
Steam boilers:			
50,000 to 95,000 BTU	1	14	2 - 3
100,000 to 250,000 BTU	1	22	2 - 3
260,000 to 450,000 BTU	1	38	4 - 6
500,000 to 750,000 BTU	1	55	4 - 6
800,000 to 1,000,000 BTU	1	85	4 - 6
1,050,000 to 1,500,000 BTU	1	135	4 - 6
Hot-water boilers:			
50,000 to 95,000 BTU	1	16	2 - 3
100,000 to 250,000 BTU	1	38	2 - 3
260,000 to 450,000 BTU	1	52	4 - 6
500,000 to 750,000 BTU	1	85	4 - 6
800,000 to 1,000,000 BTU	1	115	4 - 6
1,050,000 to 1,500,000 BTU	1	175	4 - 6
Expansion tanks:			
20 to 50 gallon	1	6	2
55 to 100 gallon	1	10	2 - 3
Fuel oil storage tanks above grade:		See table 14-8	

BTU = British thermal units

Note: All piping and wiring not included. Boilers are iron-sectional with insulating jackets and safety devices. Subtract 20 percent for steel packaged boilers.

TABLE 14-5
INSTALLATION OF HOT-WATER STORAGE HEATERS

Work element description	Unit	Man-hours/unit	Crew size
Hot-water storage heaters.			
50 to 75 gallon	1	10	2
80 to 150 gallon	1	16	2 - 3
155 to 300 gallon	1	36	3 - 6 ¹

¹ Needs forklift truck or else additional men to move and position.

Piping and wiring not included.

TABLE 14-6
INSTALLATION OF CARPENTRY AND GENERAL SHOP EQUIPMENT

Work element description	Unit	Man-hours/unit	Crew Size
Carpentry equipment:			
Bandsaw, 18-inch	1	10	2 - 3
Bandsaw, 28-inch	1	14	2 - 3
Table saw, 16-inch	1	18	2 - 3
Cut-off saw, 18-inch	1	16	2 - 3
Disk sander, 18-inch	1	10	2 - 3
Jointer, 12-inch	1	8	2 - 3
Lathe, 60-inch ¹	1	24	4 - 5
Planer, 24 by 8-inch	1	30	3 - 4
Shaper, 4-inch vertical lift	1	6	2 - 3
General shop equipment			
Bench grinder	1	2	1
Pedestal grinder	1	8	2
Drill press, ½ to 1-inch ¹	1	4	2 - 3
Drill press, 1½ to 2½-inch ¹	1	8	2 - 3
Power hacksaw, 16-inch	1	26	3 - 4
Pipe threader, ½ to 4-inch	1	8	2 - 3

¹Light work equipment for wood.

A forklift or handtruck is needed to move any of the above equipment.

TABLE 14-7
INSTALLATION OF MACHINE AND METAL SHOP EQUIPMENT

Work element description	Unit	Man-hours/unit	Crew Size
Machine shop equipment:			
Hydraulic bender	1	15	2 - 4
Hydraulic press, 100 ton	1	12	2 - 3 ³
Hydraulic press, 400 ton	1	18 ¹	3 - 4 ³
Lathe, 13 by 78-inches	1	35	2 - 4 ³
Lathe, 25 by 144-inches	1	70	5 - 7 ²
Milling machine	1	50	4 - 6 ³
Planer	1	42	3 - 4
Shaper, 24-inch	1	20	3 - 4
Drill press, 4-foot arm, 2-inch chuck	1	48	4 - 6 ²
Metal shop equipment:			
Brake, 60-inch — 18 gage	1	18 ¹	3 - 4 ³
Brake, 96-inch — 14 gage	1	32 ¹	5 - 7 ³
Brake, 120-inch — 11 gage	1	40 ¹	5 - 7 ³
No. ½ universal iron worker	1	38	2 - 4 ³
Shear, 96-inch — 18 gage	1	25 ¹	4 - 6 ³
Shear, 96-inch — 11 gage	1	28 ¹	4 - 6 ³
Bandsaw, 26-inch	1	18	2 - 3 ³
Roll, 48-inch	1	8	2 - 3

¹Does not include construction of special bases.

²Item must be moved on rollers to prevent twisting.

³Requires one or two forklifts to move.

TABLE 14-8
INSTALLATION OF WARM AIR FURNACES

Work element description	Unit	Men-hours/unit	Crew Size
Warm air furnaces:			
50,000 to 100,000 BTU/hour	1	22	2 - 3
100,000 to 150,000 BTU/hour	1	34	2 - 3
150,000 to 300,000 BTU/hour	1	52	2 - 4
300,000 to 600,000 BTU/hour	1	75	2 - 4
600,000 to 1,000,000 BTU/hour	1	120	3 - 5
1,000,000 to 2,000,000 BTU/hour	1	150	3 - 5
Fuel oil storage tanks (manufactured):			
200 to 500 gallon	1	10	2 - 3
1,000 to 2,000 gallon	1	20	3 - 4
3,000 to 5,000 gallon	1	40	4 - 6
Furnances are complete with fans, filters, safety controls, and oil burners. Does not include ducts.			

Metal Work

Chapter



TYPES

Metal work includes erection of structural and miscellaneous steel, fabrication and erection of sheet metal, and fencing.

ERECTION OF STRUCTURAL AND MISCELLANEOUS STEEL

The labor for erection of structural steel includes unloading, erecting, temporary bolting, plumbing, leveling, high strength bolting, and/or welding. Miscellaneous steel erection includes unloading, setting in place, plumbing, leveling, and fastening (usually by bolting or welding).

SHEET METAL

This includes the fabrication and erection of gutters, downspouts, ridges, valleys, flashings, and ducts. Fabrication is usually done in the sheet metal shop and includes making patterns, cutting, forming, seaming, soldering, attaching stiffeners, and hauling to site. Erection includes unloading, storing on site, handling into place, hanging, fastening, and soldering.

INSTALLATION OF FENCING

The installation of fencing includes digging holes; unloading and distributing materials; setting, plumbing, aligning, and concreting posts; installing braces; setting, stretching, and fastening fence fabric; installing caps and/or brackets on posts; installing gates, including hardware; stringing lone and barbed wire.

ESTIMATING TABLES

Tables 15-1 through 15-3 may be used in preparing detailed man-hour estimates for metal work.

TABLE 15-1
STRUCTURAL STEEL ERECTION

Work element description	Unit	Man-hours/unit
Handling (unloading steel from truck to a ground location at the erection site)	ton	1.5
Erection of steel, erect, bolt, and plumb only ¹	ton	5.
Foundation work	ton	5.
Column and struts		7.
Beams and channels		5.
Plate girder		5.
Crane rails		5.
Knee braces		9.
Floor plates		7.
Fittings, bolts, rods, and anchor plates		3.
Girt, angles, angle braces, purlins		7.
Skylight frames and curbs		10.
Monitor frames		12.
Dormers		10.
Door frames		12.
Roof trusses		9.
Transmission towers		16. - 30.
Light steel trestles		12. - 24.
Steel mill buildings		4. - 12.
Steel frame multistoried buildings		3. - 10.
Temporary bolting ² (3 to 10 bolts/ton)	100 bolts	6.
Bolting, high-strength (15 to 30 high-strength bolts/ton)	100 bolts	5.
Riveting, air driven ³		
On ground, easy work	100 rivets	8.
Trusses	100 rivets	10.
Steel office buildings	100 rivets	12.
Steel mill buildings	100 rivets	12.
Light trestles and towers	100 rivets	18.
Riveting, hand driven		
Easy work	100 rivets	14.
Difficult work	100 rivets	21.
Welding ⁴ (5-10 feet of ¼ weld/ton)	100 linear feet	22.

¹For the erection of steel in these tables, the crew consists of 1 foreman, 1 crane operator, and 4 ironworkers. A crew size can vary considerably with respect to the different factors involved, and the user of these tables should take this into consideration.

²For bolting, the crew in this table consists of 4 bolters and 1 helper.

³The riveting crew size in this table is 5 workers: 1 helper, 1 catcher, 2 riveters, and 1 helper to handle air compressor and hoses.

⁴Welding crew is 2 welders and 1 helper.

TABLE 15-2
SHEET METAL WORK

Work element description	Unit	Man-hours/unit
Roof ridges ¹	100 linear feet	2.5
Roof valleys	100 linear feet	2.5
Roof flashing	100 linear feet	8.
Roof gutters	100 linear feet	4.
Downspouts	100 linear feet	4.
Ducts ²		
100 square inches or less ³	10 linear feet	1. - 3.
100 to 400 square inches	10 linear feet	2. - 5.

¹The crew for this portion of the table is 3 workers: 1 skilled laborer and 2 helpers.

²The crew here is 1 mechanic (skilled laborer) and 1 helper.

³The size here means that in 10 feet of length the duct will have 100 square inches or less of surface area.

TABLE 15-3
INSTALLATION OF FENCING

Work element description	Unit	Man-hours/unit
Install wood fence 4" high	1,000 square feet	54
Install metal fencing 5' high chainlink	1,000 linear feet	219
8' high chainlink	1,000 linear feet	243
Hang gates	leaf	8

Suggested crew size:

Digging operations: 1 equipment operator, auger truck

Fencing operations: 4 to 6 laborers

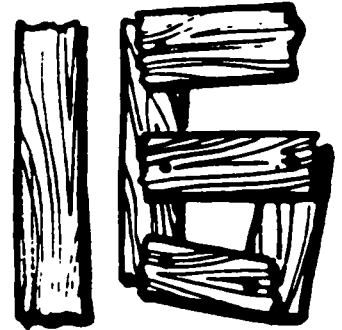
Notes:

1. Fence installation includes: Digging holes, unloading and distributing materials, setting, plumbing, aligning and concreting posts, installing braces, stretching and fastening fence fabric, installing caps or brackets on posts, and stringing line and barbed wire.

2. Hanging gates includes installation of hardware.

Waterfront Construction

Chapter



TYPES

Waterfront construction includes pile driving, pile bracing, pile capping, pier framing, installation of deck hardware, and pile extraction.

EQUIPMENT SELECTION

The type of driving and extracting equipment used can have a considerable effect on the time required for this work. A steam, diesel, or drop hammer may be used to drive piling. A steam or air extractor or a pulling beam with blocks and cables may be used for pile extraction. The equipment used affects the time required for a given unit of work. The estimator should know what equipment is to be used.

PILE-DRIVING WORK

This includes assembling leads and hammer, preparing equipment for driving, sharpening pile tips, installing steel tips on wood piles, squaring and trimming pile butts, cutting holes in steel piles to facilitate handling, moving driver into place, placing pile in leads, driving pile, and cutting pile to required grade.

PILE-BRACING INSTALLATION

The installation of pile bracing includes cutting bracing, drilling, handling into place, and fastening.

PILE-CAPPING WORK

Wood or steel pile capping includes cutting, drilling, handling into place, and fastening. Concrete pile capping includes forming, reinforcing, placing concrete, curing concrete, and stripping forms.

SHEET-PILING INSTALLATION

The installation of sheet piling includes preparation of leads and equipment for driving, preparation of pile for driving, placing pile in leads, driving pile, cutting and bracing pile, and installing deadmen and tiebacks.

PIER-FRAMING INSTALLATION

The installation of pier framing includes the cutting, drilling, handling, and fastening of stringers, bridging, all decking, rails, and bumpers.

DECK HARDWARE INSTALLATION

The installation of deck hardware includes required drilling, handling, and fastening of bits, bollards, chocks, cleats, and pad eyes.

PILE EXTRACTION

This includes rigging equipment and extracting and handling piling. It also includes cutting piles below water level and carrying pieces to stockpiles.

ESTIMATING TABLES

Tables 16-1 through 16-8, on pages 16-3 through 16-6, may be used in preparing detailed man-hour estimates for waterfront construction. The tables do not include delivery of materials to the jobsite.

EXAMPLE OF TABLE USE

The example below illustrates the use of tables 16-1 through 16-8 for making a man-hour estimate for waterfront construction.

Problem. A pier to be enlarged will require 200 50-foot wood-bearing piles. Because the pier is located between several buildings, the piles cannot be prepared adjacent to the pile-driving area. In this case, increase the time for placing and driving by 15 percent because an additional crane will be needed to transport the prepared piles to the driving area (see note on table 16-1). Work requirements are as follows:

200	50-foot wood bearing piles
400	horizontal pile braces
800	diagonal pile braces
640	linear feet wood pile caps
800	linear feet stringers
2,500	square feet decking
2,500	square feet wearing surface
350	feet bull rail
20	feet bumper
10	cleats

Solution.

Description	Units	Man-hours/unit	Subtotal
Preparing piles	200.	2.	400.
Driving piles	200.	1.7	340.
Rigging equipment	4.	6.	24.
Cutting pile at level	200.	.2	40.
Dismantling equipment	4.	6.	24.
Horizontal braces	400.	1.	400.
Diagonal braces	800.	.8	640.
Pile caps	.64	100.	64.
Stringers	2.4	40.	96.
Decking	2.5	20.	50.
Wearing surface	2.5	16.	40.
Bull rail	.35	60.	21.
Bumpers	.02	36.	1.
Cleats	10.	2.	20.
Total man-hours			2,160.

TABLE 16-1
PILE DRIVING—WOOD BEARING PILES ¹

Work element description	Unit	Man-hours/unit
25-foot pile	each	
Preparation		1.5
Drive		.5 ²
50-foot pile	each	
Preparation		2.
Drive		1.5 ²
75-foot pile	each	
Preparation		2.5
Drive		3. ²
Rigging leads and hammer (2-3 workers)	each	6.
Cut pile at required level	each	.2
Dismantle leads and hammer	each	6.
Lash piles to form dolphin	each	1.5

¹Typical crew: 1 leader, 6 workers; 10 men when placing dolphins.

²If additional crane is required to support construction, increase figures by 15 percent.

TABLE 16-2
PILE DRIVING—STEEL BEARING PILES ¹

Work element description	Unit	Man-hours/unit
25-foot pile	each	
Preparation		1.5
Drive		.8 ²
50-foot pile	each	
Preparation		2.
Drive		2.3 ²
75-foot pile	each	
Preparation		2.5
Drive		4.5 ²
Rigging leads and hammer (2-3 men)	each	6.
Cut pile at required level	each	.3
Dismantle leads and hammer	each	6.

¹Typical crew: 1 leader, 6 workers

²If additional crane is required to support construction, increase figures by 15 percent.

TABLE 16-3
PILE DRIVING—PRECAST CONCRETE BEARING PILES ¹

Work element description	Unit	Man-hours/unit
20-foot pile, complete	each	.5
40-foot pile, complete	each	1.5
60-foot pile, complete	each	2.5
80-foot pile, complete	each	3.5
100-foot pile, complete	each	5.

¹Typical crew: 1 leader, 8 workers

TABLE 16-4
PILE BRACING AND CAPPING ¹

Work element description	Unit	Man-hours/unit
Bracing ²	each	
Horizontal		1.
Diagonal		.8
Capping	1,000 linear feet	
Wood		100.
Steel		150.
Concrete		200.

¹ Typical crew: 1 leader, 6 workers.

² Table based on 4 inches x 10 inches x 4 feet bracing members.

TABLE 16-5
SHEET PILING ¹

Work element description	Unit	Man-hours/unit
Wood (20 feet deep)	1,000 square feet	
Preparation		4.
Drive		35.
Bracing		20.
Cutting		1.5
Steel (30 feet deep)	1,000 square feet	
Preparation		6.
Drive		50.
Bracing		30.
Cutting		2.
Concrete (30 feet deep)	1,000 square feet	
Preparation		35.
Drive		75.
Bracing (steel)		30.
Cutting		4.
Install deadman and tieback	each	24.

¹ Typical crew: 1 leader, 6 workers.

TABLE 16-6
PIER FRAMING ¹

Work element description	Unit	Man-hours/unit
Stringers	1,000 board foot measure	40
Bridging	1,000 linear feet	40
4-inch deck	1,000 square feet	20
2-inch wearing surface	1,000 square feet	16
Bull rail	1,000 linear feet	60
Bumper	1,000 linear feet	36

¹ Typical crew: 1 leader, 10 workers.

TABLE 16-7
DECK HARDWARE ¹

Work element description	Unit	Man-hours/unit
Bits	each	3
Bollards	each	4
Chocks	each	3
Cleats	each	2
Pad eyes	each	1

¹ Typical crew: 1 leader, 4 workers.

TABLE 16-8
PILE EXTRACTION ¹

Work element description	Unit	Man-hours/unit
Pile removal		
Piles with extractor	each	1.5
Sheet piling with extractor	1,000 square feet	25.
Sheet piling with crane	1,000 square feet	20.
Cut pile below water level	each	1.
Pile disposal	each	.5

¹ Typical crew: 1 leader, 4 workers.

Chapter 17

Other Estimating Requirements



WRECKING AND SALVAGING

SIMPLE PROCEDURES

Only relatively simple procedures are currently used by the Army engineers to wreck structures. Far less effort is made to salvage construction materials than was formerly the case, since labor costs have increased more than material costs. The salvage of marine vessels is a separate subject and is covered in TM 55-503.

USE OF ESTIMATING TABLE

Table 17-1 may be used to prepare preliminary man-hour estimates for wrecking and salvaging land structures. Because of the great variations in capacity in wrecking equipment, only the roughest labor estimates are included here. The table does not provide for moving equipment to the site or hauling salvaged materials.

TABLE 17-1
WRECKING AND SALVAGING STRUCTURES¹

Work element description	Unit	Man-hours/unit
Wood	1,000 cubic feet	12
Brick	1,000 cubic feet	20
Stone	1,000 cubic feet	24
Steel	1,000 cubic feet	18
Reinforced concrete	1,000 cubic feet	24

¹ Typical crew: 1 leader, 8 workers.

EXAMPLE OF TABLE USE

Problem. Sixteen wooden barracks are to be demolished. Salvageable material is minimal, but includes parts of furnaces. Labor is largely unskilled, but four crews can work simultaneously. Tractors are available. Each barracks contains 36,000 cubic feet (60 x 30 x 20) or 36 units. Using average man-hour estimates in table 17-1, find the total man-hours to perform the work.

Solution. Since each unit requires 12 man-hours, total work estimate is $36 \times 12 \times 16 = 6,912$. Thus, approximately 6,900 man-hours are needed to complete this task.

REMOVING SNOW

TYPES OF SNOW REMOVAL

Snow removal includes the salting or sanding of roads and airfields, the plowing of roads and airfields by a 5-ton dump truck with plow or grader, snowblowing, and the shoveling of sidewalks by workers or garden tractor. Hauling of snow is not included because this activity is similar to earthmoving with front loaders and dump trucks (see chapter 6).

EQUIPMENT SELECTION

Table 17-2 divides snowfalls into three types: light (under 2 inches), medium (2 to 6 inches), and heavy (over 6 inches). For light snowfalls, use salt to melt ice or sand to provide traction on the roads. A salt truck spreads salt or sand most efficiently although spreading can be done by shovelers spreading salt or sand from the backs of dump trucks. For a medium snowfall, graders, which are able to clear wide paths at relatively high speeds, are the most efficient snow removal equipment for main roads. Snowplows mounted on 5-ton dump trucks are used for secondary roads. For heavy snowfalls and large accumulations, snow blowers are a necessity to discharge the snow over the high snow banks which build up on both sides of the road. Plows are used to move snow to the sides of the road. While graders alone cannot handle heavy snowloads, they are used continuously during a heavy snowstorm to keep main roads open.

ESTIMATING TABLE

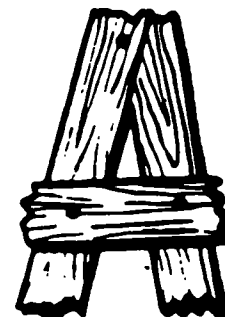
Table 17-2 may be used to prepare preliminary man-hour estimates for snow removal.

TABLE 17-2
SNOW REMOVAL

Work element description	Equipment	Unit	Equipment-hours/unit
Roads and airfields:			
Light snowfall (less than 2 inches) (salting and/or sanding)	salt truck	mile (15' width)	.2 ¹
	dump truck and shovels	mile (10' width)	.35 ¹
Medium snowfall (2 to 6 inches) (plowing)	5-ton dump with plow grader	mile (6' width) mile (10' width)	.15 .18
	5-ton dump with plow heavy duty blower	mile (6' width) mile (6' width)	.25 .15
Sidewalks:			
Light snowfall (less than 2 inches)	men	1,000 linear feet	1.8
	sidewalk tractor	1,000 linear feet	.25
Medium snowfall (2 to 6 inches)	men	1,000 linear feet	2. - 4.
	sidewalk tractor	1,000 linear feet	.25 - .35
Heavy snowfall (over 6 inches)	men	1,000 linear feet	4. + .5 per inch over 6 inches
	sidewalk tractor	1,000 linear feet	.35 + .06 per inch over 6 inches

¹ Includes refill time.

Appendix



Work Element Checklist

BUILDING

Remove existing structures
 Clearing and grubbing
 Layout
 Blasting
 Grading
 Fill, place and compact
 Landscaping, seeding and sodding
 Excavation and backfill
 Relocate existing utilities
 Concrete foundations and footings
 Pipe sleeves
 Under floor conduit and plumbing
 Transformer vault
 Grade beams
 Ground floor slab
 Jet anchor bolts or plates
 Concrete columns, beams, girders
 Concrete floor and roof slabs
 Precast wall and roof panels
 Precast structural members
 Precast sills and lintels
 Concrete canopy and entrances
 Tread and nosings
 Pipe sleeves and openings
 Structural steel

BUILDING

Masonry—concrete block, brick, structural tile
 Flashing
 Framing floors, walls, roofs, stairs
 Sheathing walls and roof
 Subflooring
 Door bucks and frames—wood
 Door bucks and frames—metal
 Overhead doors
 Window frames
 Conduit in slabs and walls
 Piping in walls
 Electrical rough-in
 Plumbing rough-in
 Siding—wood
 Metal siding and roofing
 Hoods and ventilators
 Insulation, roof
 Roofing
 Asphalt or wood shingles
 Ductwork
 Intercom system
 Telephone switchboard equipment
 Alarm systems, burglar, fire
 Electric service
 Telephone service

BUILDING

Wallboard
Lathing
Stairways
Metal studs and partitions
Insulation, walls and ceilings
Downspouts and gutters
Fire escape
Ladders
Platforms and catwalks
Roof scuttles
Exterior doors
Screen doors
Windows
Window screens
Jalousies
Exterior trim
Glazing
Louvers
Cabinets
Closet units
Lockers
Bulletin
Mirrors and medicine cabinets
Paneling
Interior doors
Metal doors
Metal toilet partitions
Security grills
Plastering
Ceramic tile
Electric fixtures
Plumbing fixtures
Finish flooring
Tile flooring, asphalt, rubber, vinyl, cork
Acoustical tile
Interior trim
Handrails
Caulking
Painting
Curbs and walks
Parking areas
Fencing
Cleanup
Air conditioning
Compressed air systems
Dehumidifiers
Dry cleaning equipment

BUILDING

Exhaust fan
Fire protection systems
Generators
Heating system
Laundry equipment
Pumps
Refrigerators
Shop equipment
Ventilation equipment
Mess equipment
Water coolers
Hospital equipment

OUTSIDE UTILITIES

Clearing and grubbing
Blasting
Trenching and ditching
Backfill and compact
Erosion control
Water mains
Water service lines
Sanitary sewer service lines
Valves
Valve boxes
Manholes
Water storage tanks
Water pumps
Sewage pumps
Storm sewers and manholes
Catch basins
Culverts
Culvert head and wingwalls
Sewage treatment plants
Poles
Cable
Transformers
Telephone cable
Underground duct
Conduit risers
Manholes and handholds
Street lights
Security lights
Control devices
Capacitors and voltage regulators

PLANT OPERATIONS

Stripping quarry
 Drilling and blasting
 Handling and loading quarried material
 Hauling to crusher or job
 Setting up crusher plant
 Operating crusher
 Stockpiling crushed material
 Hauling crushed material to plants or job
 Setting up asphalt plant
 Operating asphalt plant
 Hauling asphalt to job
 Setting up concrete batch plant
 Hauling concrete to job
 Manufacturing concrete block—all sizes
 Manufacturing precast concrete units—all types
 Hauling precast units to job
 Reinforcing steel fabrication
 Prefabricating doors, windows, jalousies, louvers, frames
 Prefabricating stairs, cabinets, closet units
 Prefabricating concrete pipe

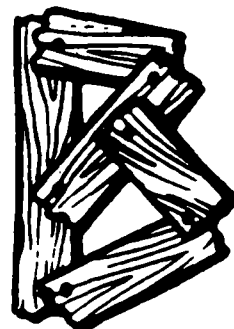
ROADS, PAVING, AND WALKS

Clearing and grubbing
 Blasting
 Cut and fill
 Grading
 Trenching and ditching
 Move and change interfering utilities
 Culverts
 Head and wingwalls
 Catch basins
 Storm drainage
 Prepare subgrade, subbase, base
 Fine grading
 Erosion control
 Asphalt tack coat
 Spread and roll asphaltic concrete
 Spread and roll chip and gravel coats
 Concrete paving forms
 Reinforcing steel and dowels
 Expansion and contraction joints
 Finishing and curing
 Concrete curbs complete
 Concrete walks complete
 Asphalt curbs complete
 Asphalt erosion protection
 Asphalt walks complete
 Precast curbs installed

WATERFRONT CONSTRUCTION

Sheet piling
 Pile dolphins
 Pier piling
 Pile capping
 Pier framing
 Pier decking
 Pier deck hardware
 Pile extraction
 Tiebacks and deadman
 Seawalls
 Dredging

Appendix



Trends in Network Analysis

COMPUTERS

The combining of network analysis techniques and computers for planning, scheduling and control in the late 1950s resulted in significant savings in time and money. During the last two decades, many managers in civilian industry and in the government have incorporated variations of network analysis into their management information systems.

METHODS

Two of the most widely used methods of network analysis are the program evaluation and review technique (PERT) and the critical path method (CPM). PERT addresses probability and is primarily used in research and development projects. CPM in the arrow format is effectively being used in the following areas:

- Construction
- Maintenance
- Warehousing
- Design
- Military Combat Tasks
- Manufacturing
- Transportation
- Logistics Systems
- Book Writing

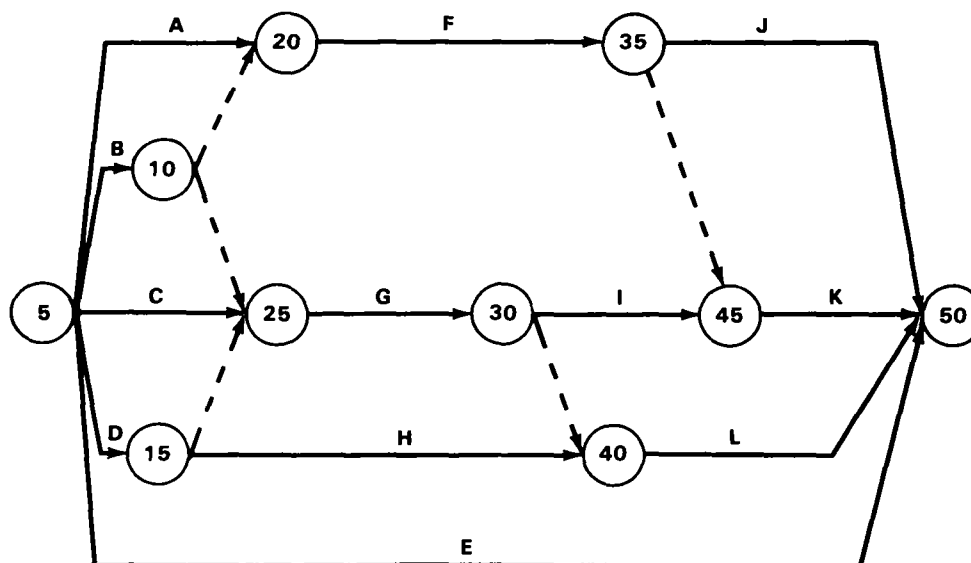
These applications are not limited to the civilian sector but are also part of the planning in many government agencies. The US Army Engineer School has taught CPM in the Engineer Officer and Advanced Noncommissioned Officer courses since the middle 1960s.

PRECEDENCE DIAGRAMING

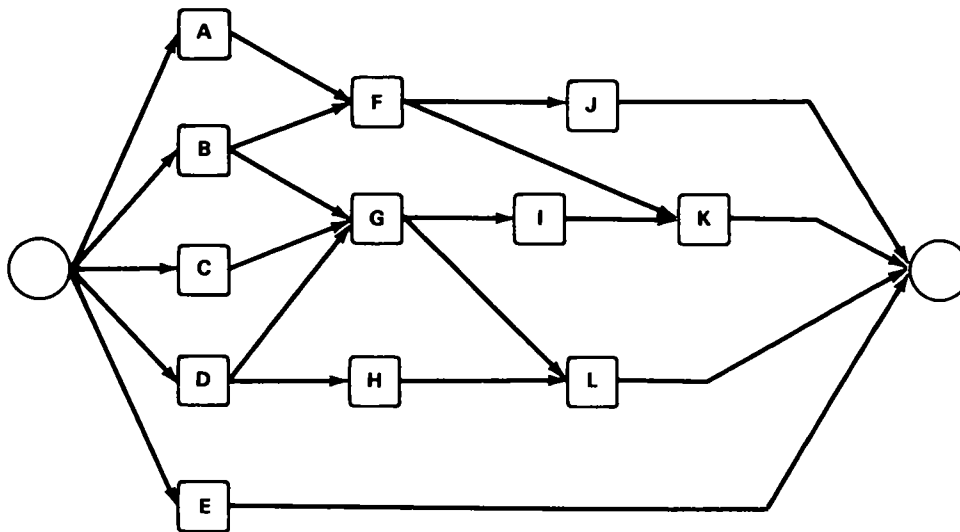
Today, one form of the critical path method is receiving widespread attention in civilian industry. This variation of the critical path method is called "precedence diagraming" or activity-on-the-node diagraming (AON).

A significant change is the graphic representation of the activity or task in the diagram. Precedence diagraming uses a node to represent the activity instead of the more commonly used arrow representation (figure B-1 and B-2). The precedence arrow is used as a connector, like the event node in activity-on-the-arrow diagraming (figure B-3). This simple change can greatly simplify the military planner's use of CPM and increase the use of network analysis in military planning and scheduling.

FIGURE B-1
ACTIVITY-ON-THE-ARROW FORMAT



**FIGURE B-2
ACTIVITY-ON-THE-NODE FORMAT**



**FIGURE B-3
DIAGRAM SYMBOLS**

ACTIVITY—ON—NODE

ACTIVITY—ON—ARROW



ACTIVITY SYMBOLS



EVENT SYMBOLS



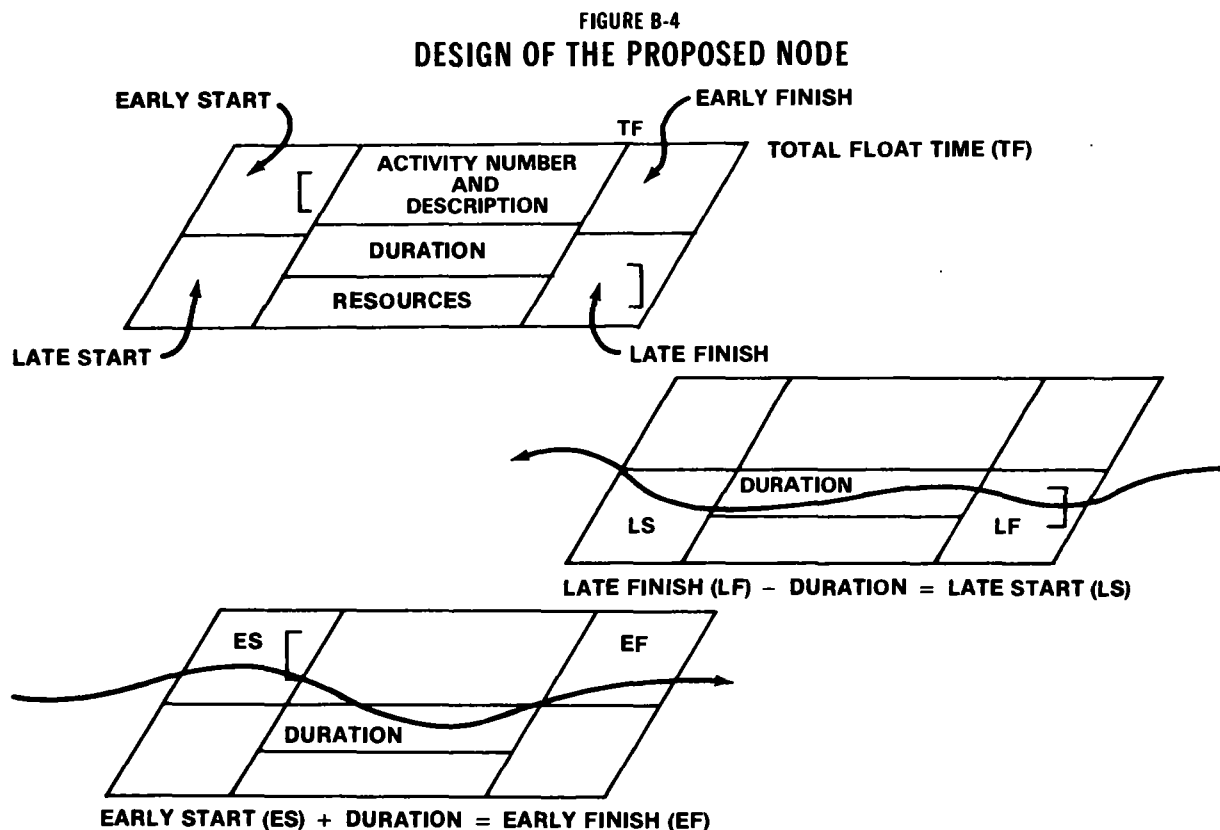
ADVANTAGES OF NODE

A major advantage of the node format to the military planner is that the format readily lends itself to the use of preprinted, gummed labels which can be typed. This eliminates extensive, time-consuming lettering and drafting. The diagram can be corrected simply by placing a new node over the old one or by adding nodes and arrows as necessary.

Less Confusion. Another important difference is the elimination of the logic and numbering dummy arrows. The dummy arrow is a source of possible logic errors for the planner and is extremely confusing to the field supervisor. In the arrow format, approximately 30 percent of the diagram is usually dummy arrows, and the number of dotted lines overwhelms many potential users.

Error Reduction. This relatively simple change to the precedence or node format of network diagramming offers the planner the advantage of being able to quickly create a diagram of a project with reduced chance of error.

Readability. The mechanics of the diagram time analysis are exactly the same for either format. Grouping all data for an activity in one place, as in the node method, greatly reduces the possibility of simple math errors that may occur using the arrow format. The design of the proposed node (figure B-4) lends itself to rapid calculations, since the eye tends to lean forward on the early time pass and backward on the late time calculations.

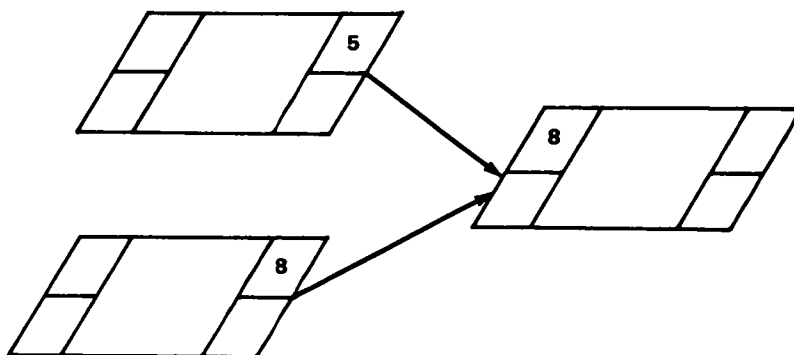


GENERAL RULES

The time analysis calculations are done according to the following general rules:

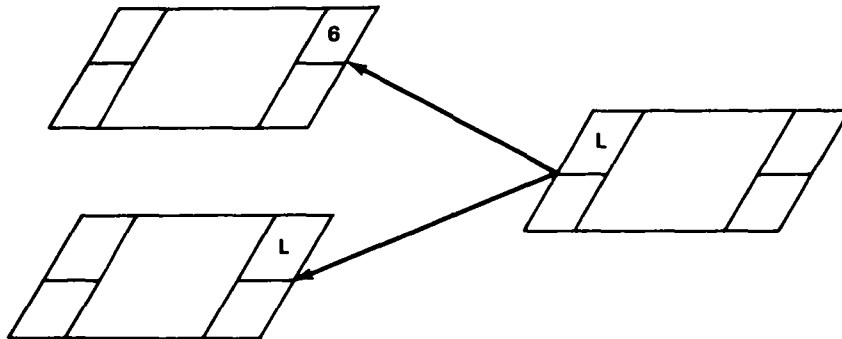
- Early finish (EF) time = early start (ES) time + activity duration.
- If more than one connecting arrow ends at a node, use the largest early finish time at the tail of the arrows as the early start time for the node (figure B-5). In other words, the work represented by the activity node cannot start until all the activities preceding it have been completed. The general flow is always from the tail to the head of the connecting arrows in the early time calculations.

FIGURE B-5
CONNECTING ARROW USING LARGEST EARLY FINISH TIME



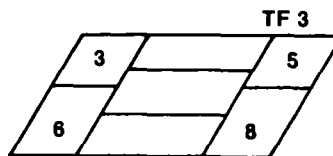
- Late start (LS) time = late finish (LF) time - activity duration.
- If more than one connecting arrow leaves a node, use the smallest late start time at the head of the arrows as the late finish for the node at the arrow's tail (figure B-6, on page B-6). On this pass through the network, remember to work generally from right to left, going from the head to the tail of the connecting arrows. This is exactly the opposite of the early time pass through the network.

FIGURE B-6
CONNECTING ARROW USING SMALLEST LATE START TIME



- Critical activities are those activities in which both pairs of times (ES & LS and EF & LF) are equal. The critical activities will form a continuous chain or path through the network and are usually marked by a heavy or double line.
- The total float time available for any activity can be calculated by taking the difference between any pair of times (ES & LS or EF & LF), as shown in figure B-7.

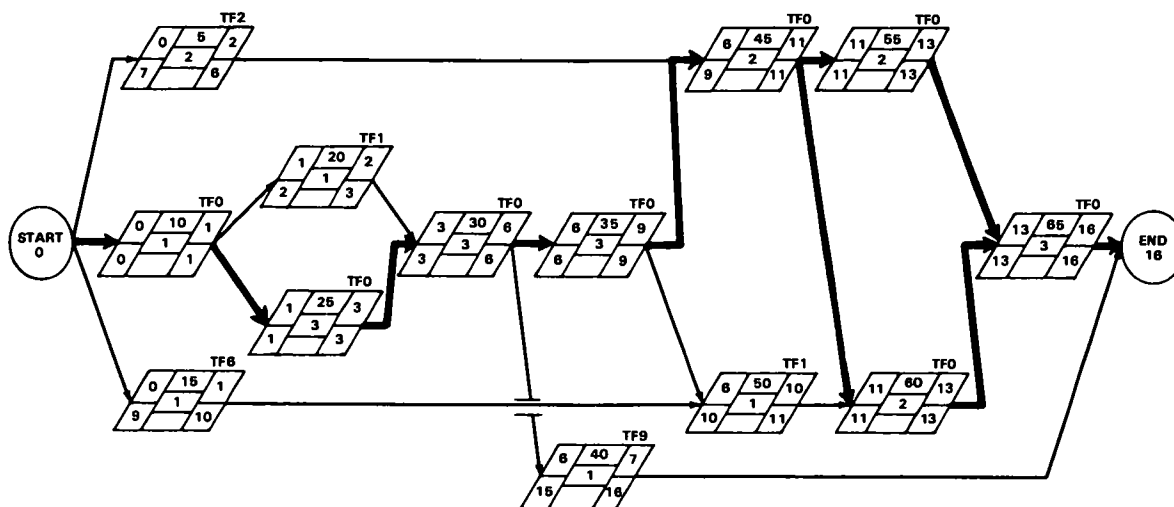
FIGURE B-7
TOTAL FLOAT TIME



EXAMPLE

Figure B-8 shows a completed network time analysis for a project. The required activity descriptions and resources have been omitted.

FIGURE B-8
COMPLETED NETWORK ANALYSIS



Schedule Listing. The next major step is the development of the schedule. There is only one significant difference between the two methods. In the node format, in order to show the relationship of one activity to others, we must list the activity numbers of all succeeding activities related to the one listed. Using the previous example, the schedule listing would appear—

Activity Number	Succeeding Activities
Start	5, 10, 15
5	45
10	20, 25
15	50
20	30
25	30
30	35, 40
35	45, 50
40	Finish
45	55, 60
50	60
55	65
60	65
65	Finish

There are no other differences in the development of the schedule or the identification of free and interfering float.

Advantages. The advantage of the node format for scheduling is the accuracy of the information. Errors in extracting the activity data amidst the squares, circles, triangles and parentheses have always been a serious problem for users of the arrow format. The node has all the information in one location. The proposed preprinted node also eliminates confusion in marking the activity time frames on the schedule. The positions of the left and right brackets are already printed on the node.

RESOURCE CONSTRAINTS

The manual procedure for balancing a schedule due to limited resources and the need to update the network has always caused confusion because of the number of dummies required to show the new constraints (figure B-9). While no method can eliminate all the problems associated with limited resources, the node method greatly reduces the confusion (figure B-10). The resource dummy is the only dotted line used and is easily identified as a constraint caused by resource limitations. There is no change in the identification process used to determine the source of the resources required to enable the activity to be accomplished. Both figures (B-9 and B-10) are based on the same example.

FIGURE B-9
CONFUSION OF DUMMIES TO SHOW NEW CONSTRAINTS

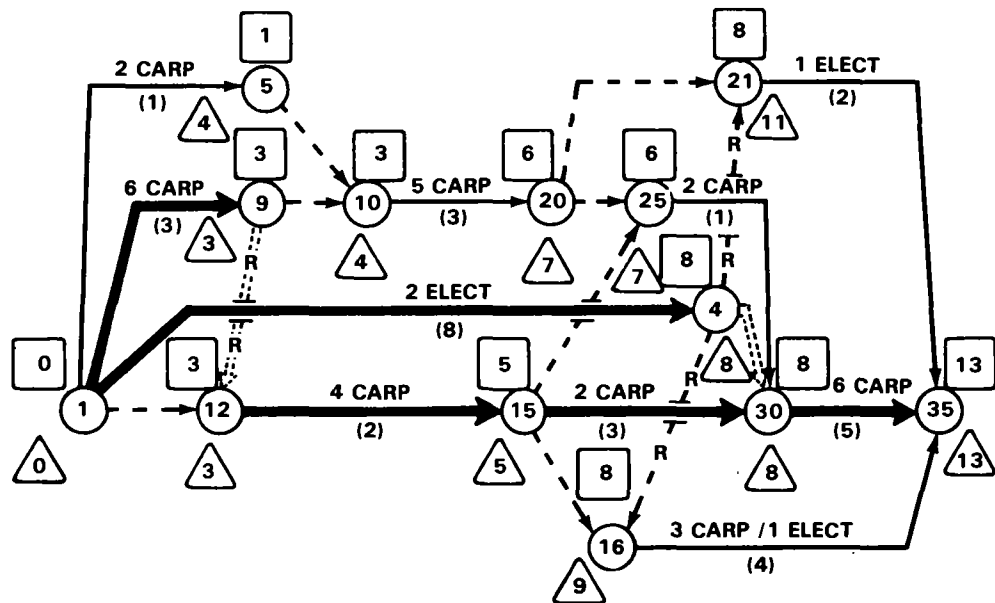
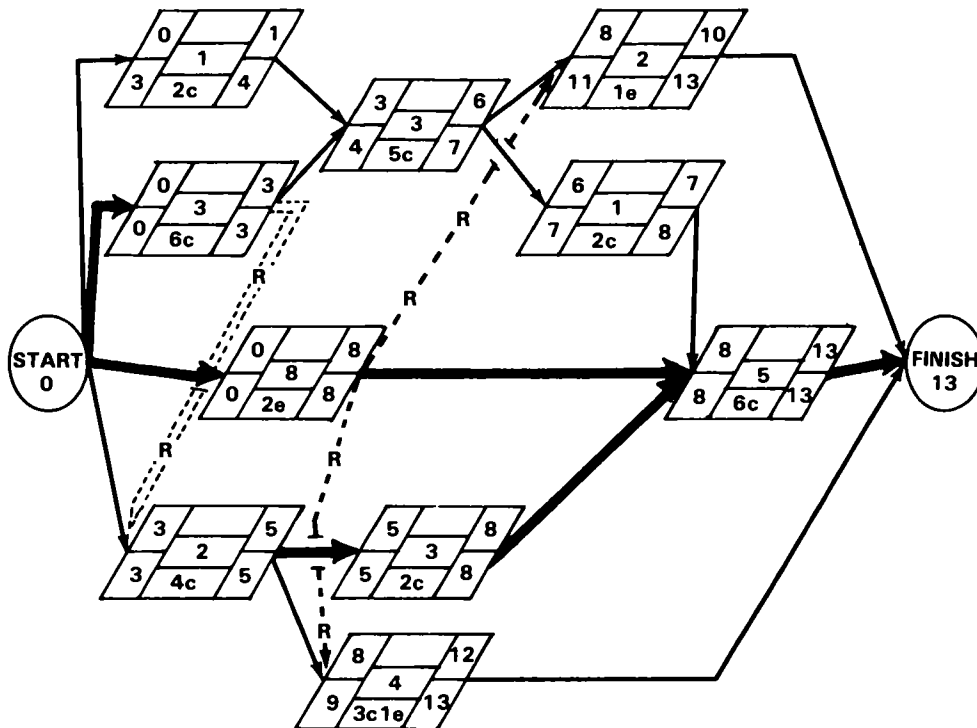


FIGURE B-10
USING THE DOTTED LINE AS A RESOURCE DUMMY

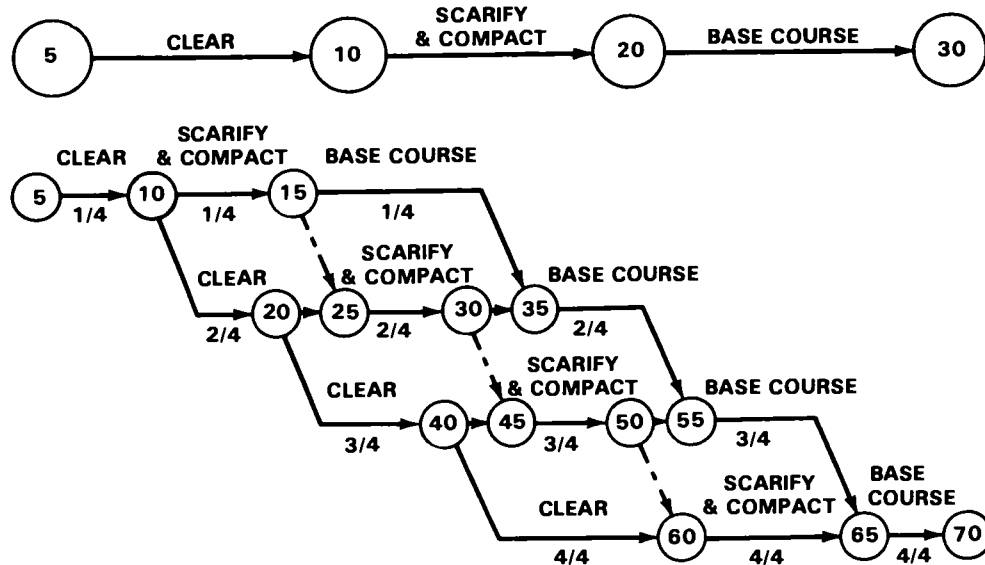


LAG FACTORS

A major problem that occurs with the activity-on-the-arrow method is showing that one activity does not have to be completely finished before a following activity can be started.

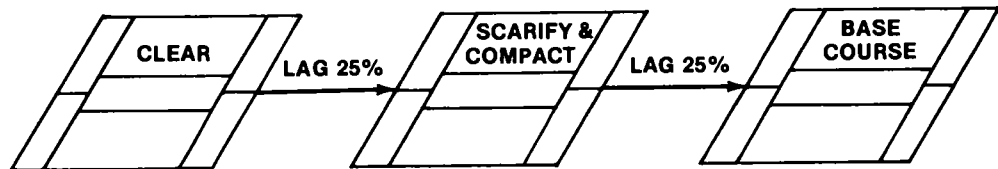
Ladder Effect. One procedure used to show this situation is to break the activity into parts to show the relationship. This creates a ladder effect as illustrated in the example (figure B-11, on page B-10) of a road project in which only one-fourth of an activity must be completed before the succeeding activity may start. This common sense procedure is awkward to diagram and also greatly increases the size of the schedule.

FIGURE B-11
LADDER EFFECT



Node Format. Simple notes are used in the node format to indicate lag factor, that is, how much of the activity must be completed before the next one can start (figure B-12). The term “lag factor” means that the start of the following activity lags behind the preceding activity by some part of the activity duration.

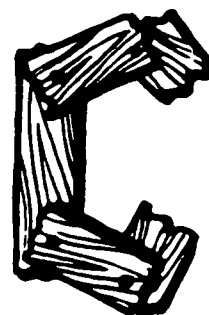
FIGURE B-12
LAG FACTOR



This concept is further explained in many texts and there are established procedures to handle any complex situation. For our purposes, this simple method is a powerful tool when measured against the number of dummies necessary in the arrow format.

SUMMARY

Although CPM in the arrow format has been used in military planning for many years, the military manager is not limited to using only this format in project planning. Many advantages of the precedence diagram (node format) have been outlined in this chapter. However, it is important to note that both formats of network analysis have advantages as well as disadvantages.



Appendix

Conversion Factors

TABLE C-1
METRIC CONVERSION FACTORS

Multiply:	By:	To Obtain:
centimeters	0.0328	feet
centimeters	0.394	inches
cubic centimeters	0.061	cubic inches
cubic feet	0.0283	cubic meters
cubic inches	16.4	cubic centimeters
cubic meters	35.3	cubic feet
cubic meters	1.31	cubic yards
cubic yards	0.765	cubic meters
feet	0.305	meters
gallons	0.00379	cubic meters
inches	0.0254	meters
liters	0.0353	cubic feet
kilograms	0.0011	tons
kilograms	2.2	pounds
meters	3.28	feet
miles	1.61	kilometers
pounds	0.454	kilograms
tons (short, 2,000 pounds)	907.	kilograms

Detailed guidance for the application and use of the International System of Units (Système International d' Unités) (SI) in place of the US customary units of weights and measures (formerly "English" or British System) and the Metric System (until 1960) is contained in NBS MP 286, NASA SP-7012, ASTM Designation E 380-70, and AASHTO Designation R 1-70. TM 5-302 and FM 5-35 contain expanded tables of equivalents useful to the engineer construction estimator in the theater of operations.

TABLE C-2
CONVERSION AND WASTE FACTORS

Material	Conversion	Percent waste
Concrete construction		
Concrete (1:2:4)		
Cement	6.0 sack/cubic yard	10
Fine aggregate	0.6 cubic yard/cubic yard	10
Coarse aggregate	1.0 cubic yard/cubic yard	10
Curing compound	0.5 gallon/100 square foot	10
Forms		
Footings and piers		
2 x 4	1.5 linear foot/square foot of contact surface	20
2 x 8	0.2 linear foot/square foot of contact surface	10
2 x 12	0.7 linear foot/square foot of contact surface	5
Ground slabs		
1 x 4	0.1 linear foot/square foot area	20
2 x 4	0.1 linear foot/square foot area	5
Walls and columns		
2 x 4	1.3 linear foot/square foot of contact surface	20
Plywood (50% reuse)	0.5 square foot/square foot of contact surface	5
Beams and susp slabs		
1 x 6	0.3 linear foot/square foot of contact surface	5
2 x 4	0.5 linear foot/square foot of contact surface	20
2 x 10	0.1 linear foot/square foot of contact surface	10
4 x 4	0.4 linear foot/square foot of contact surface	5
4 x 6	0.1 linear foot/square foot of contact surface	5
Plywood	0.5 square foot/square foot of contact surface	5
Form oil	0.5 gallon/100 square foot	10
Tie wire	12.0 pound/ton	10
Snap tie wedges	0.1 each/square foot of contact surface	5
Snap ties	0.1 each/square foot of contact surface	5
She bolts	0.1 set/square foot of contact surface	5
Nails (board foot lumber + square foot plywood, ordered as thousand foot board measure)		
6d box	6 pound/thousand foot board measure	10
8d common	4 pound/thousand foot board measure	10
16d common	6 pound/thousand foot board measure	10

TABLE C-2 (CONTINUED)
CONVERSION AND WASTE FACTORS

Material	Conversion	Percent waste
Beams and susp slabs (continued)		
20d common	2 pound/thousand foot board measure	10
6d duplex	4 pound/thousand foot board measure	10
8d duplex	9 pound/thousand foot board measure	10
16d duplex	9 pound/thousand foot board measure	10
Reinforcing steel		
#3	0.4 pound/linear foot	10
#4	0.7 pound/linear foot	10
#5	1.0 pound/linear foot	10
#6	1.5 pound/linear foot	10
#7	2.0 pound/linear foot	10
#8	2.7 pound/linear foot	10
Trim		
6d finish	7 pound/1,000 linear foot	10
8d finish	14 pound/1,000 linear foot	10
Lumber		
Framing	—	15
Sheathing	—	25
Flooring	—	25
Roofing	—	25
Wall board	—	15
Trim	—	10
Steel erection		
Rivets	25 each/ton	10
Bolts (field)		
Temporary	5 each/ton	5
Permanent	25 each/ton	5
Sheet metal	—	10
Roofing		
Corrugated steel (6 inch end lap)		
26 inch width	115 square foot/square	10
27.5 inch width	122 square foot/square	15
Wood shingles		
16 inch (4 inch exposure)	900 each/square	15
18 inch (6 inch exposure)	600 each/square	15
24 inch (8 inch exposure)	450 each/square	15
Nails (4d)	4 pound/1,000 shingles	15
Built-up roofing (4 ply)		
Sheathing paper	1 square/square	20
Felt	4 square/square	20
Pitch	125 pound/square	10
Gravel	400 pound/square	10

TABLE C-2 (CONTINUED)
CONVERSION AND WASTE FACTORS

Material	Conversion	Percent waste
Tiling		
Floor tile		
Asphalt, vinyl, asbestos	—	10
Primer	5 gallon/1,000 square foot	20
Adhesive	10 gallon/1,000 square foot	20
Cleaner	5 gallon/1,000 square foot	20
Wax	5 gallon/1,000 square foot	20
Acoustic tile		
Tile	—	10
Cement	25 gallon/1,000 square foot	20
Glass and glazing		
Glass		
8 x 12	75 panes/box	10
10 x 16	45 panes/box	10
12 x 20	30 panes/box	10
14 x 24	22 panes/box	10
16 x 28	16 panes/box	10
Glazing clips	—	10
Putty		
8 x 12	0.6 pound/pane	20
10 x 16	0.8 pound/pane	20
12 x 20	0.9 pound/pane	20
14 x 24	1.1 pound/pane	20
16 x 28	1.4 pound/pane	20
Caulking		
Primer	2 gallon/1,000 linear foot	10
Compound (½ x ½)	13 gallon/1,000 linear foot	10
Painting		
Metal		
Enamel	0.2 gallon/100 square foot	10
Zinc white	0.2 gallon/100 square foot	10
White lead	0.2 gallon/100 square foot	10
Wood		
Enamel	0.2 gallon/100 square foot	10
Zinc white	0.2 gallon/100 square foot	10
White lead	0.3 gallon/100 square foot	10
Varnish	0.2 gallon/100 square foot	10
Flat	0.2 gallon/100 square foot	10
Gloss	0.3 gallon/100 square foot	10
Brick, concrete, plaster		
Enamel	0.2 gallon/100 square foot	10
Zinc white	0.3 gallon/100 square foot	10
White lead	0.4 gallon/100 square foot	10
Varnish	0.2 gallon/100 square foot	10
Flat	0.3 gallon/100 square foot	10
Gloss	0.4 gallon/100 square foot	10
Size	0.3 gallon/100 square foot	10
Primer	0.3 gallon/100 square foot	10
Calcimine	0.4 gallon/100 square foot	10

TABLE C-2 (CONTINUED)
CONVERSION AND WASTE FACTORS

Material	Conversion	Percent waste
Plumbing		
Pipe		
Cast iron	linear foot	10
Clay, vitrified	linear foot	10
Asbestos cement	linear foot	10
Plastic	linear foot	10
Wrought iron, G.V., B.I.	linear foot	10
Copper	linear foot	10
Grooved steel (invasion)	linear foot	10
Fittings		
Cast iron		
2" and smaller	each	10
6" and smaller	each	10
8" and smaller	each	5
Clay and concrete		
4" to 10"	each	10
12" to 24"	each	5
Plastic	each	10
Wrought iron	each	10
Copper	each	10
Grooved steel	each	5
Valves		
Globe and gate		
2" and smaller	each	5
2½" and larger	each	3
Check		
2" and smaller	each	3
2½" and larger	each	2
Special applications	each	0
Solder, soft	pounds/100 joints	10
Copper fittings		
⅜"	0.5 pounds	
½"	0.75 pounds	
¾"	1.0 pounds	
1"	1.25 pounds	
1¼"	1.7 pounds	
1½"	1.8 pounds	
2"	2.4 pounds	
2½"	3.2 pounds	
3"	3.9 pounds	
3½"	4.5 pounds	
4"	5.5 pounds	
Solder, hard		

Note: Hard solder requirements equal 75 percent of soft per individual size 100 joints.

TABLE C-2 (CONTINUED)
CONVERSION AND WASTE FACTORS

Material	Conversion	Percent waste
Flux		
Soft solder	10 pounds/100 pounds	10
Silver braze (hard)	7.5 pounds/75 pounds	2
Lead and oakum		
Joint size	pounds/joint	
2"	2 pounds	
3"	3 pounds	
4"	4 pounds	
5"	5 pounds	
6"	6 pounds	
Oakum	1 pound per 5 pound lead	0
Electrical		
Conduit	foot	5
Wire	foot	10
Fittings	each	5
Steel		
Bolts (field)		
Temporary	5 each/ton	5
Permanent	25 each/ton	5
Riverts (field)	25 each/ton	10
Sheet		
Galvanized sheet	—	10
Copper sheet	—	10
Aluminum	—	10
Black iron	—	10
Electrode, mild steel, carbon and stainless	pounds/linear foot	10
1/8" thickness	0.064	
3/16" thickness	0.113	
1/4" thickness	0.158	
5/16" thickness	0.232	
3/8" thickness	0.345	
1/2" thickness	0.581	
5/8" thickness	0.874	
3/4" thickness	1.395	
1" thickness	2.148	

Note: Above figures are for fillets, butt, and groove welds with no backing strips.

Appendix



Typical Plant Layouts

FIGURE D-1
LAYOUT OF PRECAST CONCRETE YARD

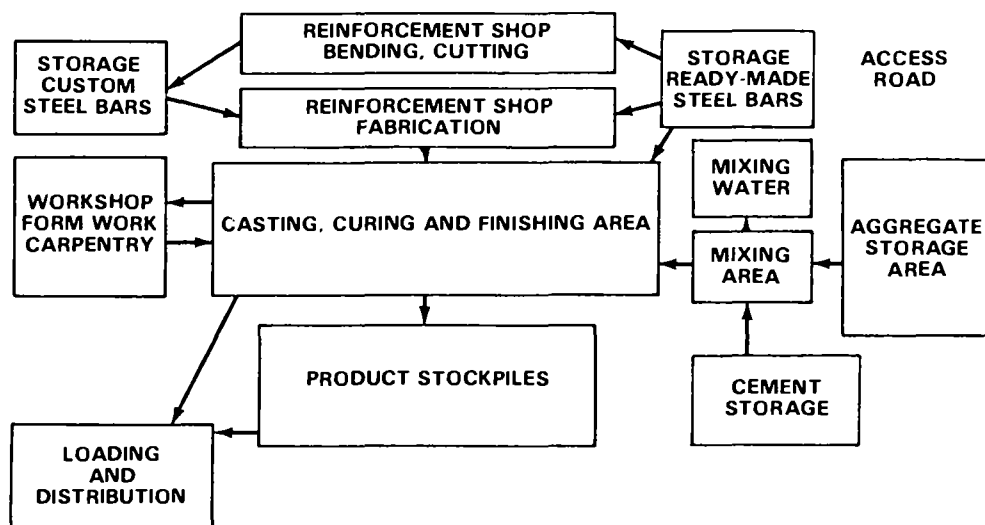


FIGURE D-2
LAYOUT OF QUARRY

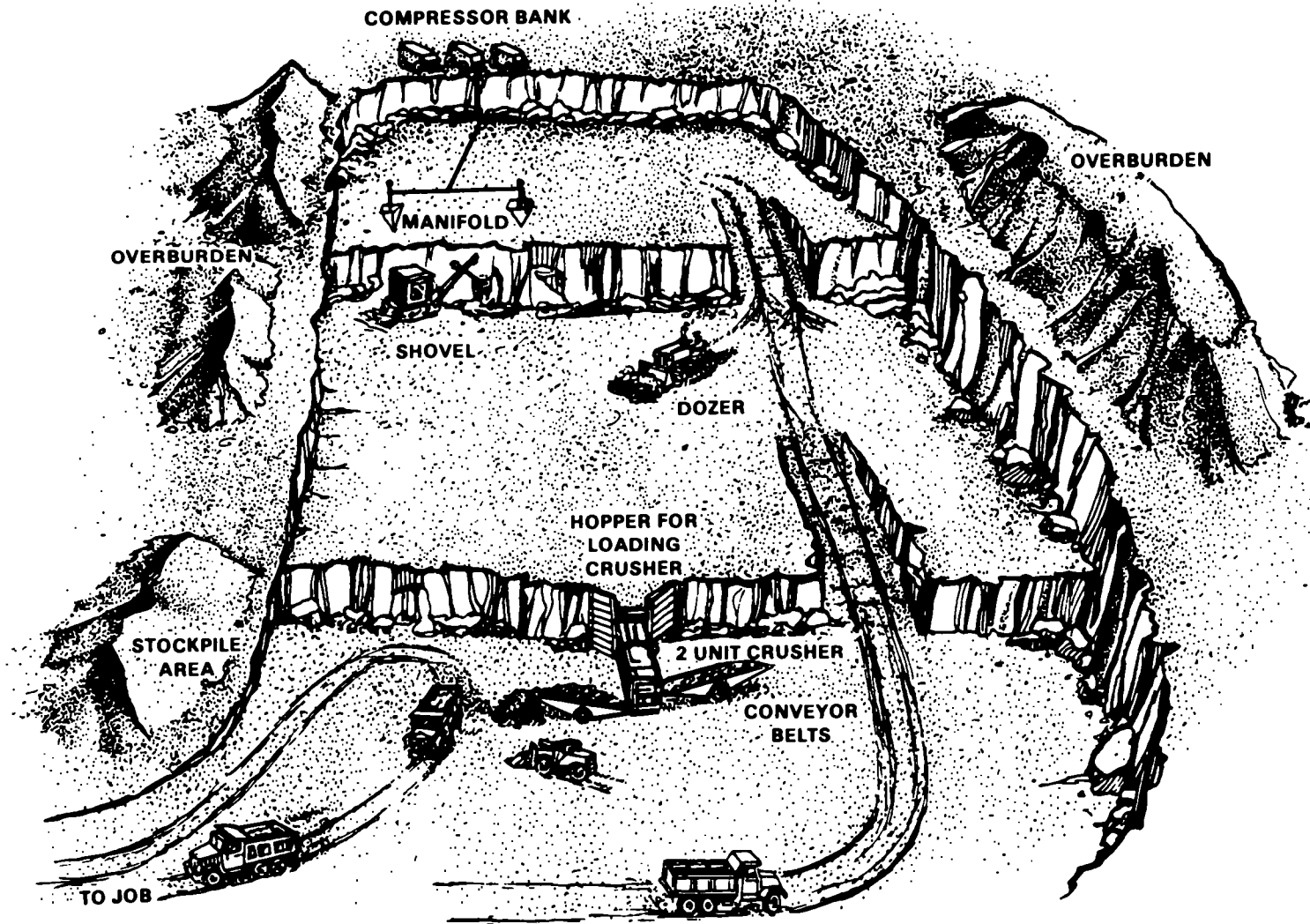


FIGURE D-3
LAYOUT OF ROCK-CRUSHING AND SCREENING PLANT

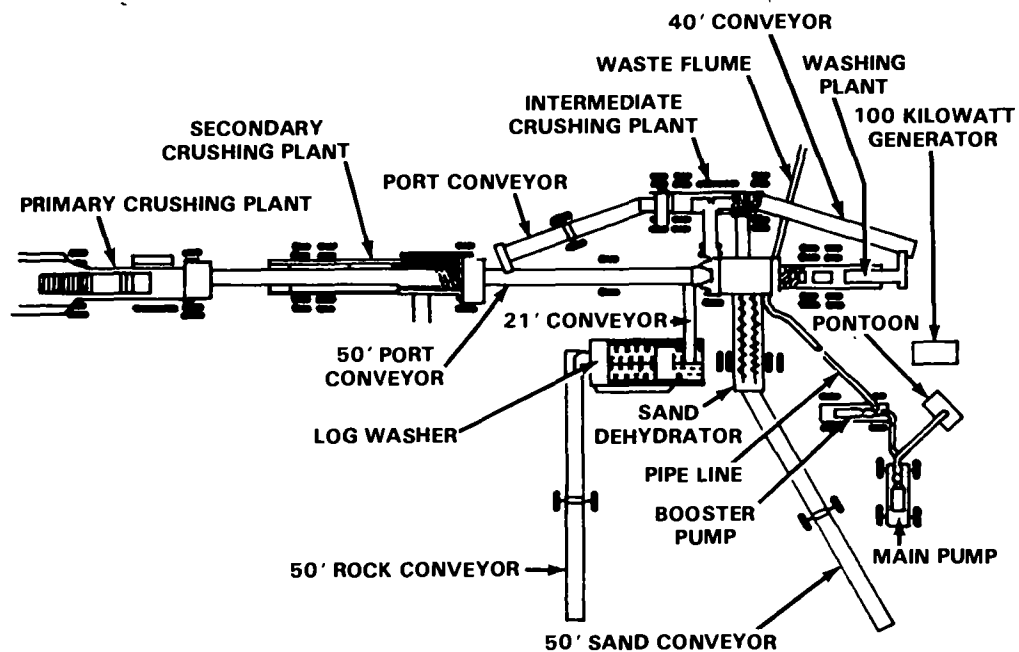
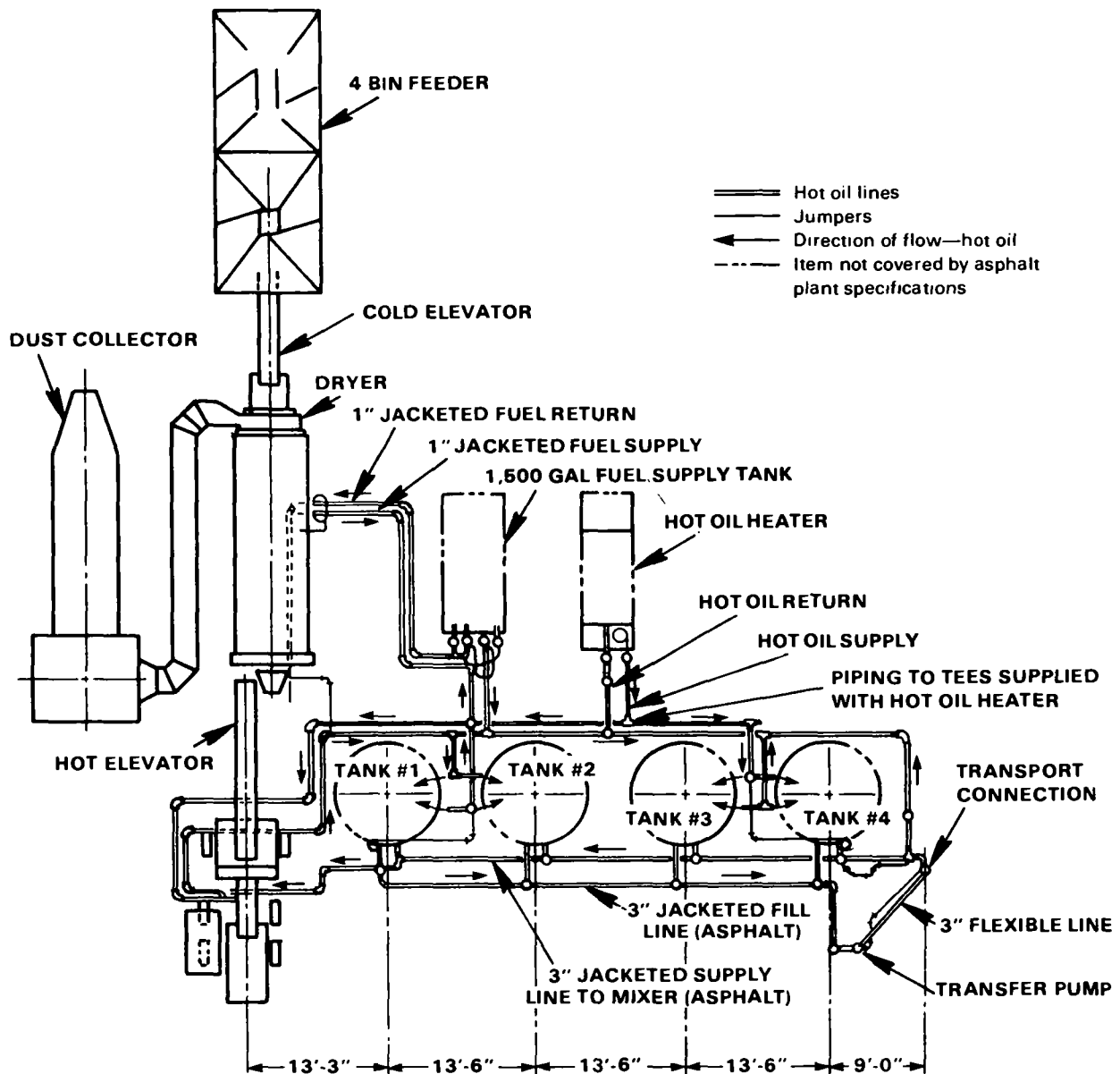


FIGURE D-4
LAYOUT OF CENTRAL MIX PLANT FOR ASPHALTIC CONCRETE



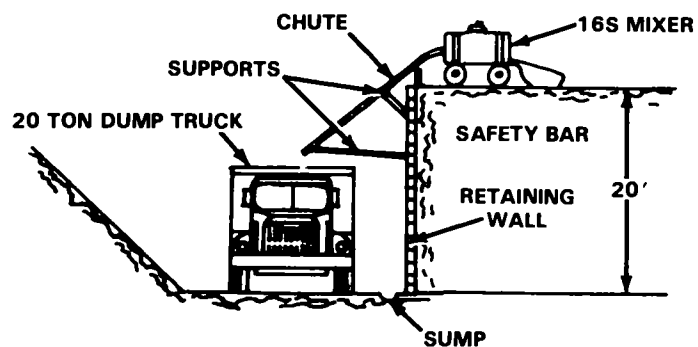
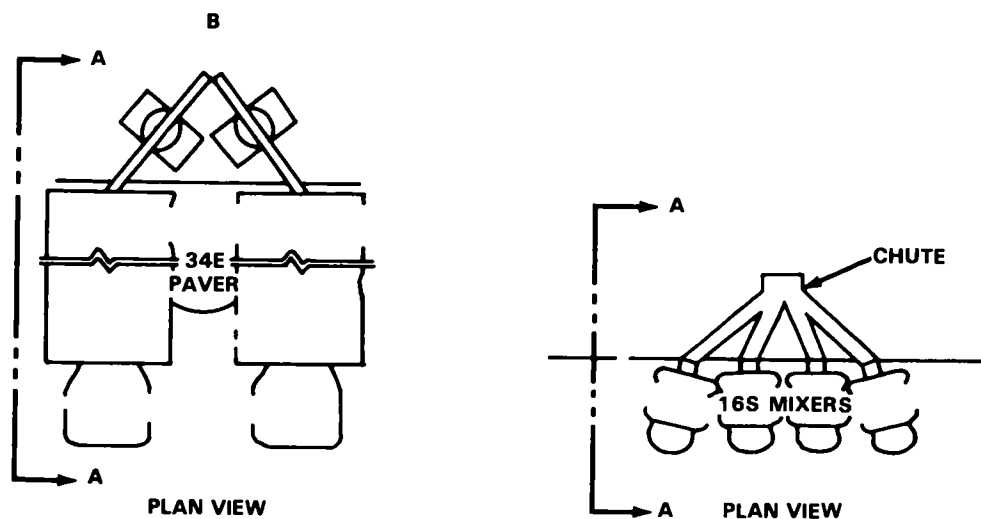
Notes:

Hot oil supply of heater is divided into the following circuits:

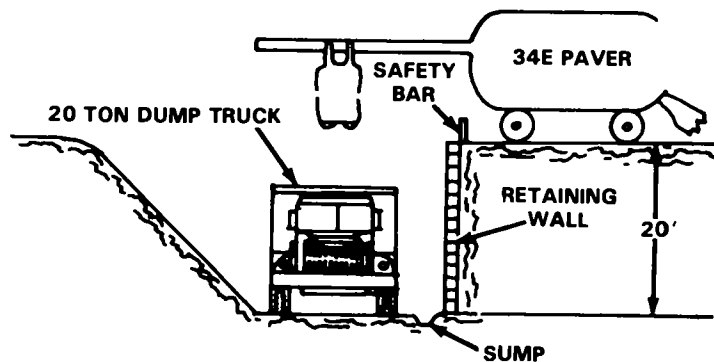
1. Mixer
2. Fuel storage tank coils and jacketed fuel lines to dryer.
3. Asphalt storage tank coils (#1 & #2), 3" jacketed asphalt fill line and transfer pump.
4. Asphalt storage tank coils (#3 & #4) and 3" jacketed asphalt supply line to mixer.

Size and type of tanks for asphalt and fuel oil may vary. Detailed information is given in TM 5-337-1 and in TM 5-331D.

FIGURE D-5
LAYOUT OF CENTRAL MIX PLANTS FOR PORTLAND CEMENT CONCRETE



SECTION AA



SECTION AA

TABLE D-1
ASPHALT PLANT OPERATION

Work element description	Units	Man-hours/unit
Set up and dismantle	each	320
Operating crushing plant	1,000 cubic yard	160
Stockpiling crushed material	1,000 cubic yard	24
Hauling crushed material to job	1,000 yard mile	48

Suggested crew size:

Setup and dismantle plant: 7 operators, 1 mechanic, 1 electrician

Operating crushing plant: 2 operators

Stockpiling crushed material: 4 operators

Maintenance (support): 1 mechanic, 1 electrician

Notes:

1. The production figure is based upon 75 tons per hour plant operating at 50 percent of rated capacity crushing granite at 3,000 pounds per cubic yard. For plants of other sizes use 50 percent of rated capacity and the size of your crew for calculations.

2. Production figures may have to be adjusted in accordance with the type of material being processed, and with other varying circumstances. For example; coral weighs (approximately) 2,000 pounds per loose cubic yard.

TABLE D-2
ROCK-CRUSHING PLANT OPERATION

Work element description	Unit	Man-hours/unit
Set up and dismantle plant	each	560
Operation of asphalt plant	1,000 tons	80
Hauling asphalt to job	1,000 ton mile	48

Suggested crew size:

Setup and dismantle plant: 4 operators, 1 electrician, 1 mechanic

Hauling asphalt to job site: 5 operators required dependent upon scope of job

Maintenance (support): 2 utilities workers, 1 electrician, 1 mechanic

Notes:

1. Figures are based on BLH 5,000 (125 tons per hour) batch plant.

2. Site preparation and concrete curing time not included in table.

Appendix



Equipment and Tool Checklist

CONCRETE WORK

Cement finishing trowels	Picks
Wooden or metal floats	Trenching equipment
Edgers	Hand levels (4-foot, 2-foot, and so forth)
Jointers	Pliers
Shovels	Mechanical finishing trowels
Concrete mixer	Rules (6-foot)
Transit mix trucks	Aggregate production equipment
Batch plant	Cement storage requirements
Weighing devices	Pumps (keep excavations free from water)
Hoisting equipment	Concrete pump
Wheelbarrow	Guniting machine
Belt conveyor	Water hose
Scaffolding	Subbase compaction equipment
Heating equipment (cold weather)	Wrecking bars
Transportation equipment	Pry bars
Curing equipment required	Concrete paving machines
Boots and Gloves, kneepads	Pointing or cleaning requirements
Vibrator (air-gas-elect)	Power tools for form work
Handtools for forming	Grinding tools
Sledge hammers	Field office requirements

MASONRY

Brick trowels
Line and line holders
Brick hammers
Pointing trowels
Mason's levels (4-foot)
Block saw and replacement blade
Joint finishing tools
Scaffolding
Mortarboards
Mixing bins or boxes
Mortar hoes
Shovels
Mortar mixer
Pliers or side cutters
Squares (framing)
Rules (6-foot)
Tapes (50- or 100-foot)
Water hose or barrels
Hoisting equipment
Transportation equipment

REINFORCING BARS

Folding rules (6-foot)
Leather gloves and jackknife
Side-cutting pliers (7-inch) •
Tape measure (50-foot)
Boltcutter (24-inch)
Hoisting equipment as required
Clawhammer
Oxyacetylene cutting equipment
Arc welding equipment
Portable shear
Portable bender
Hickey
Set of blocks ¾-inch manila line
Snatch block (for hand hoisting)
Transportation equipment
Sand screens
Floats
Rubber
Cork
Angle
Wooden
Carpet
Curing or drying equipment
Electric blowers, fan, and so forth

PLASTER

Hoisting equipment

Scaffolding requirements

Trowels
Margin
Pointing
Pipe
Angle
Plasterer's
Brushes
Browning
Finish
Tool
Straightedges
Darbies
Hawks
Mixing machine
Wheelbarrow
Mortarboards
Pliers, shears, boltcutters, and so forth, for
metal lath
Handtools, for wood lath
Mechanical plastering machine
Material storage requirements
Transportation equipment
Safety equipment, such as gloves and goggles
Water hose or pails
Transportation equipment
Expansion bit
Field office requirements
Storage area requirements

PAINT

Brushes
Spray gun
Hoses (air-paint)
Compressor
Scaffolding
Dropcloths
Paintpots
Safety equipment
Goggles
Face mask
Safety mask
Transportation equipment
Hoisting equipment
Putty knives
Paint scrapers
Wire brushes
Dusting brushes
Sanders (hand power)

Storage requirements (tarps, and so forth)
 Field office requirements
 Spare parts for spray equipment
 Hose fittings
 Paint gun extension
 Paint mixer
 Wrenches

CARPENTRY

Hammers and handles
 Saws, crosscut, rip, keyhole, and compass
 Ripping chisels
 Wood chisels
 Brace and bits
 Squares, framing, "T" and combination
 Plumb bob
 Hand levels
 Screwdrivers
 Files
 Sharpening stones
 Wrecking bars
 Pliers
 Rules (6-foot)
 Tapes (50-foot, 100-foot)
 Dividers
 Hatchets
 Nail aprons
 Pencils
 Hacksaws
 Power equipment
 Radial arms saw
 Table saw
 Jointers
 Planers
 Shapers
 Drill press
 Grinders
 Chain saws
 Routers
 Portable electrical hand saws
 Sanders
 Adzes
 Sledge hammers
 Wrenches
 Scaffolding
 Hoisting equipment

SHOP

At least one brake, 16-gage capacity
 1 sliproll for cylindrical work
 1 shear, 16-gage capacity

1 sheet metal forming machine
 1 drill press
 1 electrical hand shear
 Hand electric drill with twist drills
 Handtools per worker
 Toolbox with:

Combination square (12-inch)
 Steel tape (6-foot)
 Chisel, cold
 Punch center
 Rivet sets (set)
 Hand groovers (set)
 Dividers
 Scratch awl
 Edge Scribe
 Screwdriver
 Pliers, combination
 File
 Punch set (hand)
 Snips
 Wood mallet
 Ballpeen hammer
 Setting hammer
 Soldering iron
 Hacksaw
 Vise grip pliers
 Transportation equipment (crew-materials)

WELDING

Arc welding machines
 (such as accessories with handtools)
 Welder for shop can be permanent
 (electrical drive)
 Oxyacetylene welding and cutting outfits
 Vise
 Anvil
 Forge
 Grinding wheel (stationary)
 Drill press with complete set drill bits
 Electric hand drill with complete set drill bits
 Protective equipment
 Gloves (leather gauntlet)
 Leather jackets
 Leather aprons
 Arc welding hoods (with clear and color lens)
 Acetylene welding goggles
 (with clear and color lens)
 Face shields (clear for grinding)

EARTHWORK

Dump trucks
 Power shovels
 Draglines
 Grader
 Rollers (grid-sheepsfoot, wobble wheel)
 Cranes
 Quarry equipment
 Compressor
 Rock drills
 Rock dumps
 Crusher
 Dozers
 Scrapers
 Pushcarts
 Lubrication truck (field)
 Water truck
 Backhoe
 Ditcher
 Earth auger
 Ripper
 Jeep
 Fuel truck
 Light standards and generators
 Spare parts and tires
 Spare cables
 Air and water hose
 Low bed trailer and tractors
 Stake trucks
 High-bed trailers and tractors
 Field office equipment
 Storage area materials
 Transportation equipment
 Buses
 Stakes
 Pickups
 Jeeps
 Operator's manuals
 Repair parts manuals

PAVEMENT WORK

Graders
 Asphalt plant
 Dump trucks
 Asphalt paver
 Steel wheel roller
 Concrete paver
 Concrete spreader
 Concrete finisher
 Transit mix trucks

Concrete mixers
 Crusher
 Quarry equipment
 Compressor
 Rock drills
 Stake trucks
 Forklifts
 Front end loader
 Dozers
 Rollers for compaction
 Cranes
 Repair parts
 Field office requirements
 Transportation equipment
 Storage requirements
 Sweeper, street
 Water truck
 Water and air hose
 Hand levels
 Miscellaneous handtools for stake setting
 Aggregate drying plant
 Aggregate washing facilities
 Operator's manuals
 Repair parts manuals

OVERHEAD ELECTRICAL LINES

Block
 Climbing gear
 Brace bits
 Hammers
 Lineman's bag (tool)
 Center punches
 Pliers, long nose
 Pliers, lineman's
 Fire pot
 Lineman's gloves
 Safety strap
 Rubber gloves
 Wrenches
 Knives
 Soldering irons
 Cold chisel
 Blowtorch
 Ladle
 Plier, diagonal
 Screwdrivers
 Toolboxes
 Equipment requirements
 Storage requirements

Ladders
 Goggles
 Lighting equipment
 Saws, electrical, hand
 Chain saws
 Line truck
 Shovels
 Pole spikes
 Auger truck
 Rules (6-foot)
 Tapes (50-foot, 100-foot)
 Rope

INTERIOR WIRING

Pliers, diagonal
 Pliers, lineman's
 Pliers, long nose
 Rules (6-foot)
 Screwdrivers
 Lineman's toolbag

Wrenches
 Clawhammers
 Brace and bits
 Auger bits
 Keyhole and compass saw
 Files
 Soldering irons
 Electrician's knives
 Wire tapes
 Circuit hickies
 Blowtorch
 Fire pot
 Ladle
 Testing equipment
 Crosscut saw
 Scaffolding materials
 Storage requirements
 Safety gear
 Transportation requirements
 Toolboxes
 Tool belts

SOIL PIPE AND INTERIOR PLUMBING

Oilcan
 Cold chisels
 Round nose chisels
 Hacksaw blade

Half round file, bastard, 10-inch
 Handle, file
 Hacksaw frame adjustable
 Saw nest, keyhole and compass
 Pliers, slip (8-inch)
 Hammer, claw
 Hammer, ball (1½ pound)
 Hammer handle (14-inch)
 Wrench pipe (18-inch)
 Wrench pipe (10-inch)
 Wrench pipe (14-inch)
 Screwdrivers
 Handle, hammer, machine
 Mechanic's toolbox
 Level, 2 plumb adjustment (28-inch)
 Rule, wood folding (72-inch)
 Wire brush
 Shear, type "D"
 Reamer, pipe burring
 Cutter, pipe (4 x 6)
 Cutter, pipe (½- to 2-inch)
 Stadrills, 1 set

TOOLS

Igniters (acetylene torch)
 Marking crayon (soapstone)
 Wire brush
 Chipping hammer
 Files of various types and sizes
 Screwdrivers
 Hacksaw with blades
 Square, combination
 Square, framing
 Square, tri
 Cold chisels
 Center punch
 Crescent wrenches
 "C" clamps (various sizes)
 Chain hoist



Appendix

Consumption Factors for Expendable Supplies

Nails

Framing

8-penny common

10-penny common

16-penny common

Sheathing (8-penny common)

Flooring (88-penny casing)

Roofing (8-penny common)

Wall board (6-penny common)

4-penny finish

6-penny finish

8-penny finish

5 pounds/thousand board feet measure

15 pounds/thousand board feet measure

10 pounds/thousand board feet measure

30 pounds/thousand board feet measure

30 pounds/thousand board feet measure

30 pounds/thousand board feet measure

15 pounds/1,000 square feet Trim

3 pounds/1,000 linear feet

7 pounds/1,000 linear feet

14 pounds/1,000 linear feet

Mortar

Block (8 x 16) - $\frac{3}{8}$ joint

4-inch wall

8-inch wall

2-inch wall

0.1 cubic yard/100 blocks

0.2 cubic yard/100 blocks

0.3 cubic yard/100 blocks

Brick (2 $\frac{1}{4}$ x 8) - $\frac{3}{8}$ joint

4-inch wall

8-inch wall

12-inch wall

0.3 cubic yard/1,000 brick

0.4 cubic yard/1,000 brick

0.4 cubic yard/1,000 brick

Structure tile (12 x 12) - $\frac{3}{8}$ joint

4-inch wall

8-inch wall

12-inch wall

0.2 cubic yard/100 tile

0.3 cubic yard/100 tile

0.5 cubic yard/100 tile

Putty for Glass

8 x 12	0.6 pound/pane
10 x 16	0.8 pound/pane
12 x 20	0.9 pound/pane
14 x 24	1.1 pounds/pane
16 x 28	1.4 pounds/pane

Caulking

Primer	2 gallons/1,000 linear feet
Compound (½ x ½)	13 gallons/1,000 linear feet

Painting

Metal

Enamel	0.2 gallon/100 square feet
Zinc white	0.2 gallon/100 square feet
White lead	0.2 gallon/100 square feet

Wood

Enamel	0.2 gallon/100 square feet
Zinc white	0.2 gallon/100 square feet
White lead	0.3 gallon/100 square feet
Varnish	0.2 gallon/100 square feet
Flat	0.2 gallon/100 square feet
Gloss	0.3 gallon/100 square feet

Brick, Concrete, Plaster

Enamel	0.2 gallon/100 square feet
Zinc white	0.3 gallon/100 square feet
White lead	0.4 gallon/100 square feet
Varnish	0.2 gallon/100 square feet
Flat	0.3 gallon/100 square feet
Gloss	0.4 gallon/100 square feet
Size	0.3 gallon/100 square feet
Primer	0.3 gallon/100 square feet
Calcimine	0.4 gallon/100 square feet

References

REQUIRED PUBLICATIONS

The following publications are sources of information that must be referred to in order to understand or comply with this publication.

ARMY REGULATIONS (AR)

570-2 Organization and Equipment Authorization Tables

DEPARTMENT OF THE ARMY FORMS (DA FORM)

2028 Recommended Changes to Publications and Blank Forms

DEPARTMENT OF DEFENSE FORMS (DD FORM)

1723 Flow Process Chart

FIELD MANUALS (FM)

5-34 Engineer Field Data

5-35 Engineers' Reference and Logistical Data

5-100 Engineer Combat Operations

5-551 Carpentry

5-742 Concrete and Masonry

101-5 Staff Organization and Operations Procedures

101-10-1 Staff Officers' Field Manual: Organizational, Technical, and Logistical Data

TECHNICAL MANUALS (TM)

5-301-1 Army Facilities Components System—Planning (Temperate)

5-301-2 Army Facilities Components System—Planning (Tropical)

5-301-3 Army Facilities Components System—Planning (Frigid)

5-301-4 Army Facilities Components System—Planning (Desert)

5-302-1 Army Facilities Components System—Designs, Volume 1

5-302-2 Army Facilities Components System—Designs, Volume 2

TECHNICAL MANUALS (Continued)

5-302-3	Army Facilities Components System—Designs, Volume 3
5-302-4	Army Facilities Components System—Designs, Volume 4
5-302-5	Army Facilities Components System—Designs, Volume 5
5-303	Army Facilities Components System—Logistic Data and Bills of Materials
5-304	Army Facilities Components System—User Guide
5-330	Planning and Design of Roads, Airbases and Heliports in Theater of Operations
5-331A	Utilization of Engineer Construction Equipment, Volume A: Earthmoving, Compaction, Grading and Ditching Equipment
5-331B	Utilization of Engineer Construction Equipment, Volume B: Lifting, Loading, and Hauling Equipment
5-331C	Utilization of Engineer Construction Equipment, Volume C: Rock Crushers, Air Compressors, and Pneumatic Tools
5-331D	Utilization of Engineer Construction Equipment, Volume D: Asphalt and Concrete Equipment
5-744	Structural Steelwork
55-503	Marine Salvage and Hull Repair

RELATED PUBLICATIONS

The following publications are sources of additional information. They are not required to understand this publication.

ARMY REGULATIONS (AR)

415-series Construction

420-series Facilities Engineering

DEPARTMENT OF THE ARMY PAMPHLETS (DA PAM)

5-4-1 Management Survey Handbook

5-4-2 Work Simplification Handbook for Analysts

TECHNICAL MANUALS (TM)

5-331E	Utilization of Engineer Construction Equipment, Volume E: Engineer Special Purpose and Expedient Equipment
5-337	Paving and Surfacing Operation
5-337.1	Asphalt Plant Layout, 100- to 150-TPH
5-360	Port Construction and Rehabilitation
5-551K	Plumbing and Pipefitting

TECHNICAL MANUALS (Continued)

- 5-530** Materials Testing
- 5-652** Steam, Hot-Water, and Gas Distribution Systems; Repairs and Utilities
- 5-704** Construction Print Reading in the Field
- 5-745** Heating, Ventilating, Air Conditioning, and Sheet Metal Work
- 5-760** Interior Wiring

US ARMY SCHOOLS PUBLICATIONS

Management Views, US Army Management School, Fort Belvoir, Virginia
Resources Management Systems, US Army NRI, Bldg 215, Fort Belvoir, Virginia

Selected Readings in Management, RB 20-5, US Army Command and General Staff College, Fort Leavenworth, Kansas

US NAVY PUBLICATIONS

NAVFACP-405, Seabee Planner's and Estimator's Handbook, Department of the Navy, Naval Facilities Engineering Command, 200 Stovall Street, Alexandria, Virginia 22332

NONMILITARY PUBLICATIONS

American Association of State Highway and Transportation Officials (AASHTO). Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 444 North Capitol Street, Washington, DC 20001

Glossary

ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AFCS	Army Facilities Components System
AON	activity-on-the-node diagraming
AR	Army regulation
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
B.I.	black iron
BLDG	building
BLH	manufacturer's model identification
Bn	battalion
BOM	bill of materials
BTU	British thermal unit(s)
CARP	Carpenter(s)
CF	cubic foot (feet)
CH	soil type—inorganic clay of high plasticity (fat clay)
CL	soil type—inorganic clay of low to medium plasticity (gravelly clays, silty clays, sandy clays)
CONST	construction
CPM	critical path method
cy	cubic yard(s)
d	pennyweight
DA	Department of the Army
DD Form	Department of Defense Form
DUR	duration

EET	early event time
EF	early finish
EFF	efficiency
e.g.	for example
ELECT	electrician(s)
Engr	Engineer
ES	early start
etc.	and so forth
ft	foot (feet)
FM	field manual
fr	from
GC	soil type—clay gravel, gravel-sand-clay mixture
GM	soil type—silty gravel, gravel-sand-silt mixture
GP	soil type—poorly graded gravel or gravel-sand mixture, little or no fines
G.V.	galvanized
GW	soil type—well graded gravel or gravel-sand mixture, little or no fines
H	hour
L.CHORDS	lower chords
LET	late event time
LF	late finish
LS	late start
MH	man-hours(s) (estimates)
MH	soil type—inorganic silt, silty soil, elastic silt
min	minute(s)
ML	soil type—inorganic silt/very fine sand with slight plasticity
NCOIC	noncommissioned officer in charge
No.	number
OC	on center
OH	soil type—organic clay of medium to high plasticity, organic silts
OJT	on-the-job training
OL	soil type—organic silts and silt-clays with no plasticity
opn	operation
pcs	pieces
PECS	Prepackaged Expendable Contingency Supply

PERT	program evaluation and review technique
prefab	prefabricate(d)
raf	rafter
RST	reinforced steel tiebar
SC	soil type—clayey sands/sand-clay mixtures
sec	second(s)
SI	International System of Units
SM	soil type—silty sands and sand-silt mixtures
SOP	standing operating procedure
SP	soil type—poorly graded sands or gravelly sands, little or no fines
std	standard
stor	storage
susp	suspended
SW	soil type—well graded sands or gravelly sands, little or no fines
TF	total float
TM	technical manual
TO	theater of operations
TOE	table of organization and equipment
TOT QUANT	total quantity
trans	transfer
TRP	troop
US	United States
wk hr	work-hour(s)
YDS	yards

SYMBOLS

x	times (formulas)
x	by (measurement)
+	plus
-	minus
÷	divided by
=	equals
'	foot (feet)
"	inch(es)

#	number
&	and
%	percent
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
1st	first
2d	second
3d	third

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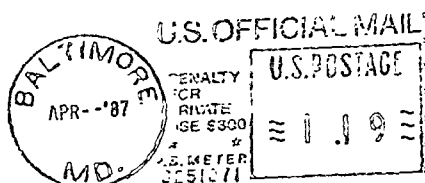
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